progreSSIon

On the occasion of 10 years TU Delft Safety & Security Institute

SAFETY & SECURITY IN A CHANGING WORLD

Safe by Design

"Engineers must learn to talk about ethics"

Field perspective

All in for safety & security

Opinion

We need an inclusive approach to flood risks

Road, air, rail

Safety & security in a transport sector on the move

Discussion

Are sustainability and safety incompatible?

TU Delft Safety & Security Institute

An institute building bridges

TU Delft

Contents

6 **An institute building bridges**
Current director of the TU Delft Safety & Security institute Benham Taebi and his predecessor Pieter van Gelder look back and towards the future.

11 **All in for safety & security**
A field perspective on safety & security from the worlds of forensics, public health, crime and public administration.

22 **"Engineers must learn to talk about ethics"**
Report of a three-day Safe by Design course for young researchers.

26 **A snapshot of safety & security in a changing world**
A drawn impression of some of the complex safety & security challenges that the world faces.

29 **"Don't let good failures go to waste!"**
The TU Delft Approach to Forensic Engineering.

34 **Safety & security in a transport sector on the move**
How can the sector deal with new challenges such as AI and the sustainability transition?

My story

Most academic researchers have a personal drive that directs their interest for certain subjects. We asked five of them to reflect on theirs.

10 **Britte Bouchaut**

21 **Zeki Erkin**

28 **Marjan Hagenzieker**

39 **Riccardo Ferrari**

44 **Nan Yue**

Opinion

Exchanging ideas is crucial for us. Some researchers share their view with you.

20 **Is safety culture a matter for the workplace, not science?**

42 **Towards system resilience in an interconnected world**

48 **We need an inclusive approach to flood risks**

50 **Are sustainability and safety incompatible?**

COLOFON
© **NOVEMBER 2023 PUBLISHED BY** the TU Delft Safety & Security Institute **PARTICIPATING FACULTIES** Aerospace Engineering, Applied Sciences, Civil Engineering and Geosciences, Electrical Engineering, Mathematics and Computer Science, Technology Policy and Management **CONCEPT & COORDINATION** Ilse Oosterlaken, Eveline Vreede, De Zagerij ontwerpbureau **EDITORIAL STAFF** Ilse Oosterlaken, Eveline Vreede, who thank the management team of the TU Delft Safety & Security Institute for their valuable inputs **DESIGN** De Zagerij ontwerpbureau **FINAL EDITING** Helen Hartmann, Ilse Oosterlaken, Eveline Vreede **PRINTED** on certified paper from sustainably managed forests

29

45 **TU Delft Safety & Security Institute helps ideas grow**
Six highlights from the seed funding programme of the Institute.

51 **The hidden research behind CSI**
How researchers working in engineering for forensics develop reliable technologies and methods for crime investigations.

54 **Safety & security in a changing world**
The last pages are dedicated to a reflective conversation on the magazines theme.

Captured

Some projects are best presented in an image. We chose five photogenic examples of interdisciplinary collaboration.

4 **Safety on a small ánd large scale**

18 **Engineering for human security**

32 **The Control Room of the Future**

40 **Beautiful and safe?**

52 **Self-adapting trailblazers**

Scan the QR code for a digital version of this magazine or more information about the TU Delft Safety & Security Institute.

Editorial

In today's world, safety & security are more important than ever, with both fields dominating the newspapers. Therefore, with great pleasure, I present to you this magazine, 'progreSSIon'. To celebrate 10 years of TU Delft Safety & Security Institute, it presents a sample of the many innovative activities at TU Delft within the extensive fields of safety & security.

Delft University of Technology has a long and strong history of research in the fields of safety & security. Still, it has never before been presented quite like in this magazine. In addition, we have added insights from some of our partners to broaden the perspective.

In my 15+ years of experience in safety & security, I observed that a lot can still be obtained by combining these fields. The safety world is still somewhat disconnected from the security world and vice versa, although many developments are comparable, and many insights could be shared. TU Delft researchers are working on a more integral approach.

Today's grand challenges can no longer be solved with a single perspective or approach. They have a strong technological component and take place in a complex setting with many stakeholders, with different values at stake and different views on the world. That is why a systems approach to safety & security is needed, which is also what the Faculty of Technology, Policy and Management, coordinator of TU Delft Safety & Security Institute, adds to these important research fields.

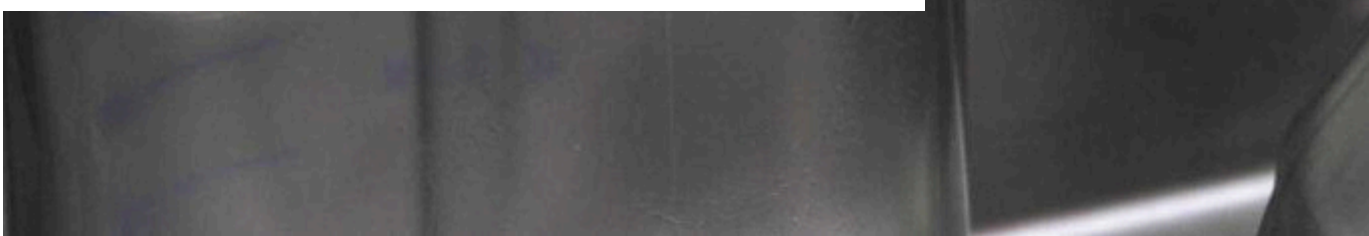
Cooperation is key, which the cross-faculty approach of TU Delft Safety & Security Institute aims to establish. This is also illustrated by this magazine, showcasing the work of researchers from many different disciplines and TU Delft faculties.

I hope this magazine brings you inspiration and new insights into the critical, challenging and fascinating world of safety & security.

Aukje Hassoldt
Dean of the Faculty of Technology, Policy and Management
Delft University of Technology

Safety on a small ánd large scale

Working with tiny particles, Ruud van Ommen and his research group hope to eventually make an impressively significant impact with their work on water purification. About 750 million people currently have no access to safe drinking water, particularly in Sub-Saharan Africa and Southeast Asia. One of the causes in Asia is groundwater contamination due to rapid industrial development. A potential solution: metal oxide-based nanoparticles that can destroy chemical and biological pollutants. “A lot of people around the globe are experimenting with nanotechnology”, says Van Ommen, “but not many can make the transition from small-scale lab findings to large-scale reality.” By combining knowledge of nanomaterials and reactor design, his group hopes to make the difference. But the lofty goal of clean drinking water should not distract from the fact that nanomaterials have also raised safety concerns, as the risks are often unknown or difficult to determine. A reason for Van Ommen to collaborate with TU Delft colleagues campus-wide on further developing the Safe-by-Design approach to engineering.



text Ilse Oosterlaken photo Global Initiative

An institute

TU Delft Safety & Security Institute

building bridges

Accidents, geopolitical tensions, and an escalating climate crisis – these are only some of the challenges that the TU Delft Safety & Security Institute has been addressing for a decade now. Do the somewhat technology-driven efforts amount to a drop in the ocean, or to a crucial building block? The current director, Behnam Taebi, and his predecessor, Pieter van Gelder, look back and towards the future.

text Merel Engelsman **photos** Sander Foederer

Safety is inherent to engineering. The legend goes that bridges built at the time of the Roman Empire were already tested for safety, also considering user perception. For this purpose, the designer/builder would stand underneath the bridge when the first carriage crossed. It is not surprising, therefore, that safety has been an integral part of the curriculum of all TU Delft faculties ever since their inception. And with the rapid development of technologies such as computer networks and information systems, and new schemes for malicious human action, security has become deeply ingrained in the university's DNA as well.

"Until about ten years ago, there used to be separate islands of safety culture at TU Delft," says Pieter van Gelder, former director and Professor of Safety Science. "But safety & security are fundamentally multidisciplinary subjects. To make real progress, we must build bridges between researchers from various faculties." Established with that in mind, the TU Delft Safety & Security Institute aims to enhance internal cohesion as well as the visibility to the outside world. "Nowadays, safety culture at TU Delft is more like an archipelago," says current director Behnam Taebi, also a Professor of Energy & Climate Ethics. "And universities, companies, and those involved in governance and policy know how to find us."

Safe by Design

Ever since its founding ten years ago, the institute has continually adapted to the high speed at which the world changes and tried to stay ahead of those developments. What hasn't changed is that the institute addresses a wide variety of safety & security issues; from geopolitics to digital developments, and from occupational safety and health to forensic investigation into what caused safety & security events. Van Gelder: "The overarching goal is to minimize undesirable events in our society, both in terms of their impact and frequency. It doesn't matter whether these are accidental events (safety) or malicious, intentional events (security). The two domains can, in fact, learn a lot from each other."

> "Our more prominent presence in The Hague supports our goal of bringing technology closer to policy and governance"

The focus of the institute has shifted somewhat when the new leadership was appointed, now four years ago. They decided to organize the themes by methodology and work in a transdisciplinary manner, integrating various scientific disciplines to address complex problems. "Our choice of themes [see box] covers all technical fields, promotes interdisciplinary collaboration with social and human sciences, and encourages collaboration with non-academic stakeholders," Taebi says. "The success of the MOOC (Massive Open Online Course) on Forensic Engineering – increasing safety by learning from past failures – is a major reason why we wanted to maintain this as a theme. And Safe by Design has become one of our most successful themes, something the institute is renowned for. We are very proud of that."

The human dimension
Both directors emphasize that research into safety & security at TU Delft may not be that different from other universities. “We tend to lean towards technological approaches,” Taebi says. “But above all, we see ourselves as part of a larger safety & security family.” An essential, as promoting safety & security requires a combination of technical, social, and humanistic knowledge. It is impressive, for instance, that airplanes can fly and land on autopilot, but sometimes a pilot needs to suddenly intervene after many minutes of inactivity. Taebi: “A lapse in attention and the socio-technical solutions to prevent this from happening are of major importance for self-driving cars. It can help prevent many unsafe situations and accidents. Additionally, TU Delft has made great effort to formally investigate safety cultures – in the cockpit of an aircraft, in the chemical industry, and in healthcare.”

“The overarching goal is to minimize undesirable events in our society, both in terms of their impact and frequency”

There are certainly topics at which TU Delft excels precisely because of its technological perspective – such as the probabilistic approach to safety & security. Van Gelder: “It is hard to underestimate the importance of this mathematical way of thinking. When it comes to flood safety, for example, you could even speak of a “Delft approach”. But it does not define us as we have significantly broadened our scope. Ethical aspects of safety & security are just as important to us. What exactly is safety, and how does it relate to other values that we as society consider important? Are safety risks distributed fairly, and who bears formal responsibility if things do go wrong?”

Techno-security
One of the current objectives is to build more bridges, in particular with parties that operate in the realm of governance and policy. As a direct consequence, the previously virtual institute that consolidated safety & security research at TU Delft has recently opened a physical location in the political capital of The Hague. Taebi: “Our more prominent presence in The Hague supports our goal of bringing technology closer to policy and governance. In our view, The Hague is the city of Peace, Justice, and Security. A perfect alignment with safety & security.”

When it comes to safety-related issues, parties involved typically assume it to require engineering expertise. But when it comes to security-related issues, the knee-jerk reaction is towards expertise in law, criminology, and psychology. “A logical reaction, to some extent, as one would like to understand the intentions behind malicious human actions,” Taebi says. “But this does not consider the fact that each safety risk also has a security component. Things that can go wrong can often also be forced to go wrong.” Consider, for instance, a circuit breaker that prevents damage to the power grid during an electrical overload. Hackers could target it, thereby compromising the reliability of electricity supply. Taebi: “What we consistently try to emphasize in our communication is that security issues can also require engineering expertise – you can engineer it to be safe by design.”

Climate Security
The war in Ukraine in particular has boosted this perspective. “It has underscored plenty of security issues,” Van Gelder says. “Food security, energy security, water security. And when it comes to transitioning to a circular economy, we are heavily reliant on imported raw materials to produce wind turbines, solar panels, and batteries. It all comes down to attaining and then maintaining strategic autonomy.”

A topic frequently touched upon during discussions is how the institute should position itself

regarding defence research. Taebi: “Until recently, the common stance or justification has been to only focus on defensive research rather than offensive research. For instance, defending ourselves against attacks on power grids or anticipating attacks on water systems. However, there is only a thin line between offensive and defensive measures, and it may at times even be non-existent. Moreover, the geopolitical realities governing the world are in constant flux.”

Thanks to ever more extreme weather conditions, climate security has become a high priority topic as well. Consider the safety & security aspects of drought, the related migration flow, or freshwater scarcity potentially leading to conflicts. “Traditionally, these topics have been primarily approached from a social and human sciences perspective,” Taebi says. “From my primary role as an ethicist and a humanities scientist, I would agree. As an engineer, however, I think that an interdisciplinary approach is warranted. It is for this reason that we recently established the TU Delft Climate Safety & Security Centre (CASS) – a new centre in The Hague. The intellectual groundwork partly stems from work performed within the TU Delft Safety & Security Institute, but it is also a broadening and a repositioning.”

More relevant than ever before

And what about the future? What developments do the two directors consider important? Van Gelder: “If we consider the COVID-19 pandemic and the war in Ukraine to be outliers, then the world has become a safer place over the past decade. It is a trend we want to see continued.” Taebi adds that this will take an increased effort as the challenges in climate, energy, and sustainability have only grown larger. “The war in Ukraine has been quite a game changer in that respect. A small side effect is that, nowadays, you hardly need to explain the relevance of safety & security research.”

Technological advancements are (rightfully) expected to play a significant role in tackling important societal challenges and to maintain the appropriate level of safety & security. But both directors expect technology itself to also increasingly contribute to the problem. Taebi points out semi-autonomous systems, such as self-driving cars. Van Gelder says that developments in AI (artificial intelligence) both intrigue and worry him. “The field advances so rapidly. Just six months ago, for example, I wouldn’t have anticipated that something like chat-GPT could be such a powerful tool. It could be quite disruptive in an already polarised society.”

One way or another, technology will (continue to) play an important role in the level of safety & security in our future world. Scientists who provide context and perspective as well as scientists who develop new applications and solutions are needed to help navigate and adapt to current and future challenges. Taebi: “The TU Delft Safety & Security Institute needs and welcomes both types of scientists.”

The four research themes of the institute in the period 2019-2023

- Uncertainty quantification & vulnerability assessment
- Safe & secure by design
- Mitigation of impact
- Forensics & failure analysis

Behnam Taebi

Studied materials science and earned a PhD in the philosophy of technology. He is a Professor of Energy & Climate Ethics at the Faculty of Technology, Policy and Management at TU Delft. He carries responsibility for the newly established TU Delft Campus in The Hague. His research interests include energy ethics and energy justice, nuclear ethics, and socially responsible innovation. He is the current scientific director of the TU Delft Safety & Security Institute (since 2019).

Pieter van Gelder

Studied mathematics and computer science and earned a PhD in civil engineering. He is a Professor of Safety Science at the Faculty of Technology, Policy and Management at TU Delft. The main focus of his research is probability analysis. This puts him more on the side of safety, but he has also spends significant effort on security research. He served as the scientific director of the TU Delft Safety & Security Institute from 2013 to 2018.

Britte Bouchaut

Britte Bouchaut grew up in Kloosterzande, a village in the Dutch Flanders part of Zeeland. She spent her childhood in this area of natural beauty around the Western Scheldt (Dutch: Westerschelde), the estuary of the Scheldt River.

Standing at the Zeedijk looking out at the horizon, you feel the river's spaciousness. Look to the right and see the nuclear plant and maritime traffic from the Port of Antwerp. To the left, you can observe seals and other wildlife and people enjoying recreational activities. The stark contrast between heavy industry and natural beauty has always been there. Still, now Britte feels a strong urge to take action and contribute to protecting this area with strong family ties as much as possible.

In the acknowledgements of her 2022 Thesis, 'Responsible Learning about Uncertain Risks', there is a humorous shout-out to her cousins, which offers insight into how involved and very personal her motivation in current research is:

Unfortunately, we cannot get the PFAS out of the Westerschelde, but we can devote more drinks to discussing it. Cheers!

"I have lived in Eindhoven for over ten years but am going home when I return to Zeeuws-Vlaanderen. My family is still there, and some of my friends stayed, too. Our conversations on current affairs and global issues at home revolve around our collective interests and professional expertise. My cousins and their partners are professionals in technology, science, health and environment sectors. Inevitably, we talk about the PFAS scandal in the Westerschelde. If only swift action was taken after the discovery of PFAS in the Westerschelde. But for me, this isn't simply about the injustice caused by multinationals. It is about our health, and we don't even know the full extent yet. My parents still live in and near Kloosterzande, along with many others I love and care about."

"If you were to ask my parents if they are surprised at my academic and professional career choices, I'm sure they would tell you they are not. I grew up in a village where everyone generally respected water and nature. They knew about my intrinsic desire to protect our planet. What bothers me is that while we can stand up for ourselves, our land and animals do not have a voice. As a child, I was like a little activist on behalf of animals. A proud member of the World Wildlife Fund and Kids for Animals, I would knock on doors to collect money!"

After my BA in Chemistry, I took a master's in Innovation Sciences at the TU in Eindhoven. I started noticing and exploring the interactions between policy and innovation. If I take a step back and reflect, my PhD at Delft is a natural confluence of my interests, frustrations and intrinsic desire to contribute to a better and safer environment.

Did Britte miss an opportunity in politics? She laughs and states she is much happier right where she is, confident that she can make a tangible contribution to change for the better.

Britte Bouchaut is assistant professor at the Safety & Security Science group at TU Delft. Her research focuses on the ethics of safety in Chemistry and Biotechnology and how we can work towards safer and more sustainable industries using Safe (and sustainable)-by-Design and Responsible Research and Innovation.

text Helen Hartmann **illustration** De Zagerij ontwerpbureau

All in for safety & security

Wanting to feel as safe as possible, society is averse to unwanted events. Whether they are attributable to incidents (safety) or malicious intent (security), unwanted events can be caused by technical imperfections, (unintended) human actions, or a combination of factors. Promoting safety & security therefore is an area of research that greatly benefits from interdisciplinary collaboration between technical, social, and humanities disciplines. New developments must also be swiftly and skilfully translatable into practice, in which various public organisations and government institutions play a significant role. We posed five questions to some of these partners of the TU Delft Safety & Security Institute, focusing on their perspectives and insights in the field of safety & security. First, an introduction of the interviewees and their specific field of work.

text Merel Engelsman

Annemieke de Vries
Director of Science and Technology at the Netherlands Forensic Institute (NFI)

The NFI, the Dutch knowledge and expertise centre for forensic research, contributes to truth-finding in (inter)national criminal investigations through applied research, knowledge transfer, and innovation. Scientific investigations include DNA and fibre analysis, decoding digital information, and many other things. Innovation encompasses technological advancements that can enhance forensic research as well as developments in other knowledge domains that can be of value to the forensic process. Moreover, innovation is not only initiated in response to past and current events, but also aimed at developing forensic techniques for tomorrow's pressing issues. The team of Annemieke de Vries coordinates, aligns and supports the innovation efforts both within the NFI and with external partners.

Marjolein van Asselt
Director of the Rotterdam Court of Audit

The Rotterdam Court of Audit is an independent scientific research institute at the municipal level. It conducts qualitative research into the policies pursued by the Rotterdam municipal council – which includes the responsibilities related to promoting safety & security. In recent years, the Court of Audit has conducted investigations into topics such as subversive crime, traffic safety, and the use of algorithms. The research also extends to the risks of public policies on the energy transition and climate change (such as water safety and heat stress). The research is mostly evaluative in nature, but the reports always provide forward-looking recommendations. It is then up to the municipal council to determine how the executive board of Mayor and Aldermen should act.

Sven Hamelink
Head of Science & Technology at the Staff of the National Police Services Agency, co-chair of the 'Programmaraad Rijks Innovatie Community', and Chair of the European Clearing Board

The Police uphold the law, maintain public order, provide aid, and conduct criminal investigations. Crime prevention is on their list of tasks as well. The Dutch police are world class in some areas of expertise, such as cybercrime and encrypted messaging (EncroChat and SKyECC, for instance). The department of Science & Technology keeps a close eye on relevant technological developments. What are the potential threats and opportunities related to these developments and how may these impact the organisation? These assessments are made internally as well as in close collaboration with European agencies, knowledge institutes, and partners in the chain in other countries. An important secondary appointment of Sven Hamelink therefore is his chairmanship of the European Clearing Board – which focuses on developing and exchanging tools and methods for crime investigation.

Jaco Westra
Coordinator Safe and Sustainable by Design at the RIVM

Jaco Westra is Coordinator Safe and Sustainable by Design within the Environmental and Safety domein at the Dutch National Institute for Public Health and the Environment (RIVM). The research he coordinates focuses on safety and sustainability, covering both scientific and policy aspects. It is strongly prevention oriented; the goal is to prevent that the development of new (chemical) substances and materials may increase the safety risks for humans and the environment. Next to substances, it also applies to new processes, installations, and systems. Rather than assessing individual substances, the focus lies on developing widely applicable instruments, such as a toolbox that companies can use for early-stage assessment of the harmfulness of a substance or material under development. This research aims to prevent health risks similar to those caused by substances such as PFAS and chromium (VI).

QUESTION 1

What is the greatest safety & security challenge in your domain of expertise or organisation?

NFI

Annemieke de Vries

Subversive crime – criminal activities that aim to undermine or destabilize established institutions, systems, or governments – is a major challenge. Drug-related crime poses a challenge for the Netherlands in particular as we play a significant international role in drug trafficking, and now also as a drug producing country. We need to seriously consider new approaches for drug crime investigation and invest in developing new methods. Digitisation is key, but it comes with several challenges: in storing, sharing, securing, searching, and utilizing data. How to do that safely and ethically? At the same time, it opens up huge opportunities as these data may provide a wealth of information.

National Police

Sven Hamelink

Technology advances at lightning speed: smart cameras, image recognition, sensors, Wi-Fi tracking, mixed reality, drones, self-driving vehicles, quantum encryption and decryption. It is too much and too impactful and needs to be assessed in a structured way. What are the opportunities and potential threats? What ethical aspects (such as privacy) come into play? Proportionality is important too. Should we, for example, use camera's to scan for someone throwing litter from a car? We need to define our position.

Rotterdam Court of Audit

Marjolein van Asselt

Security challenges often involve illegal activities, making them difficult to investigate. But a more general challenge is that safety & security has become an umbrella term. We must critically assess whether a topic really is a safety & security issue, why that is the case, and if such labelling helps to clarify and solve a problem. The label determines how the municipal council will act on our report's findings. If we label something to be a security issue then, for the time being, the council will treat it as such. When researching algorithm use, for instance, we approached this from a risk perspective. We could have approached it from an efficiency standpoint as well.

RIVM

Jaco Westra

The idea of prevention that is behind Safe & Sustainable by Design is so logical, it hardly needs explaining. The biggest challenge is to make it work. It takes a wealth of technical knowledge to be able to assess the potential hazards of a chemical substance. We need to bring all this knowledge from various disciplines together and improve on it where necessary. How to manage this and who will be the knowledge holder? At the same time, this preventive approach also requires a system change. We'll need to convince companies that this is a good idea. They may readily assume it will hinder innovation, while I believe it will help promote a more constructive discourse on innovation.

QUESTION 2

What would you like to achieve in the field of safety & security?

NFI

Annemieke de Vries

Most of our efforts are reactive in nature; we become involved only after a certain crime has occurred. I would like to see our focus shift more towards early detection and even prediction. By using intelligent data analysis (forensic intelligence) to look for patterns in the drug market, for instance. Do we observe changes in the cutting agents used to lace drugs, and can law enforcement intervene sooner by following the (digital) traces of those agents? Close collaboration between various parties is key if we want to achieve this. The recently formulated National Forensic Research Agenda helps set the stage. It is a fantastic initiative in which the entire forensic field – police, the public prosecution service, judiciary, TNO, universities, universities of applied sciences, NFI, and more – have joined forces. I can't wait to see what research collaborations this will bring forth.

National Police

Sven Hamelink

Eisenhower said that "what is important is seldom urgent and what is urgent is seldom important." I believe it to be important for our organization to have the space of mind, time, and budget to think about what creates value for tomorrow and the day after. Rather than being reactive in our response, we should be proactive in addressing the opportunities and threats that come our way. And even though the Dutch National Police is known for being quite innovative, only a fraction of all technological innovations make it into actual practice. I would like to see that change. This doesn't mean (even) more collaboration, but smarter collaboration with other relevant parties – such as academia, research institutions, and companies.

Rotterdam Court of Audit

Marjolein van Asselt

In the academic world, safety & security are two largely separate topics, with each their own researchers, conferences, and scientific journals. This is problematic for assessing safety & security risks, and very inconvenient for the Court of Audit which is very much practice-oriented. We need to find the right expert for each specific safety & security issue. It would help us a lot if this could be organized in a more interdisciplinary manner. We can then enter into a partnership with a single interdisciplinary academic research institute for any topic that touches on safety & security – such as subversive crime, digital security, or climate safety.

RIVM

Jaco Westra

In an ideal world, preventive consideration of the potential safety risks posed by new substances and materials is deeply ingrained in society. It wouldn't only be a priority for the government, but also for the parties that develop the substances and bring them to market. This is not to point the finger at industry; the world has evolved the way it has. But we already know so much about chemical substances, and we already have various models for that. Preventive consideration is no fantasy, it is very much feasible. Next to technical aspects, universities also play an important role regarding the social scientific aspects. Take governance, for instance – what are the roles and responsibilities in a system that prioritizes prevention?

QUESTION 3

What is the role of technology in safety & security, both as a solution and as a risk?

NFI

Annemieke de Vries

An important non-digital development is that we can analyse ever smaller traces, both in the lab and on location. And there are many indispensable advancements in the digital realm as well. We successfully apply AI in practice, and we keep an eye on up-and-coming technologies such as the role of quantum computing in data security. Recent events in the Netherlands – with AI – have shown that we shouldn't put blind faith in technology. It is therefore essential that we carefully consider how new developments are incorporated into the criminal justice system. Moreover, a prosecutor, judge, and lawyer need to understand how we conducted our research. A key task for NFI researchers therefore is to clarify new developments, such as how we (will) prove that a certain video is not a deepfake.

National Police

Sven Hamelink

The exponential growth and convergence of technology creates new domains. Take, for instance, the convergence of developments in nano-, information-, bio-, and cognitive technology. In addition, some technology that used to be reserved for state actors is now accessible to everyone. It not only brings us new ways of working, but it also presents new threats, depending on how these new technologies influence criminal practices. If we want to fully capitalise on the opportunities offered by digitisation, I believe that the we – and the safety & security domain as a whole – need to make another step when it comes to our willingness and ability to change.

Rotterdam Court of Audit

Marjolein van Asselt

The challenge with technology is that positive expectations always outpace acknowledgment of the associated risks. First the promises and only much later – and often to the surprise of technology developers – the risk debate. But you can't have one without the other. The fire-retardant properties of asbestos were undisputed, but it came with enormous health risks. When I worked at the Dutch Safety Board, we didn't wait for automation in road traffic to lead to major accidents. Rather, we scrutinised research into near accidents and indicated that risk assessment was inadequate. And at the Court of Audit, in the report on the use of algorithms, we specifically examined whether organisation of the risk side matched that of the promises.

RIVM

Jaco Westra

The approach of Safe & Sustainable by Design can be applied at various levels of abstraction – including emerging technologies such as nanotechnology, advanced materials, or synthetic biology. At the moment, however, it is primarily being developed for chemical substances. A key technological advancement is the use of AI to make predictions – based on existing knowledge – about substances with (slightly) differing chemical structures. Companies use this to understand the characteristic properties and potential harm of a substance. Focussing on safety, the latter is of particular importance to us. We want to understand this knowledge development so that we, as a government, can assess the working of these AI models and the reliability of the outcomes they produce.

QUESTION 4

How do you view (future) collaborations with academic and non-academic stakeholders in promoting safety & security?

NFI

Annemieke de Vries

We have a large (inter)national network with universities and universities of applied sciences, with organizations such TNO, the WODC (Research and Documentation Centre), and with our partners in the criminal justice system. This variety of partnerships has led to significant progress in forensic research. We already have a strong collaboration with TU Delft in the fields of AI and data science. We are also jointly developing innovative methods for crime scene analysis, such as a biometric model for complex falls. But our interests and questions are broadening: how to apply these and other new technologies in a safe and responsible manner? Technical and ethical research can go hand in hand as TU Delft has expertise in both areas. Additionally, the National Forensic Research Agenda will significantly boost collaboration with both academic and non-academic stakeholders.

National Police

Sven Hamelink

We can't do everything ourselves, even though we are one of the largest employers in the Netherlands. It is our goal to determine who are the knowledge owners, how we can participate, and how we can make it applicable in our context. Together with research institutions and peer organizations in other countries, we have developed a Science & Technology agenda as a guiding framework in support of this goal. The required tools and solutions will be developed in labs, hubs, and pilot projects. And rather than continually entering negotiations on issues such as intellectual property rights and confidentiality, we are now establishing collaboration frameworks for these partnerships. The one with TU Delft has just recently come into effect.

Rotterdam Court of Audit

Marjolein van Asselt

Many universities appear not to realise that there are Courts of Audit that house excellent researchers doing similar work. We may be small in size, but our research does make the headlines. Moreover, city councils have the statutory duty to discuss it and the executive board must come up with a response. Put simply, societal impact is intrinsic to our work and valorisation is a core product. And where academic researchers may spend months negotiating for access to data, we simply put in a request. These aspects make it highly interesting to collaborate with a Court of Audit for any academic researcher whose knowledge is relevant to a specific municipality, major cities, and beyond. In return, we get easy access to scientific journals.

RIVM

Jaco Westra

Tremendous progress has been made in the field of chemical substance hazards. As a scientific government institute, we need to be informed about these developments. That is not something we can do on our own, nor should we want to. We therefore collaborate with numerous academic partners, such as TU Delft, Wageningen University & Research, and Leiden University, as well as many international knowledge partners. The questions and perspectives of industry and other societal partners are important too. All this shared knowledge is needed to come up with an effective prevention approach. Their contribution is also essential in bringing about a system change towards a new safety mindset.

QUESTION 5

Engineers have excellent technical-analytical capabilities. How is the engineering mindset reflected in your daily work, and how does it relate to other necessary expertise?

NFI

Annemieke de Vries

Innovation at the NFI is mostly driven by forensic practice and by the developments we or our partners observe in the outside world. The NFI is furthermore firmly grounded in the natural sciences. It means that we need scientists – including engineers – to translate the needs and developments regarding a topic such as organised crime into new approaches and innovation projects. And to subsequently develop the new tools. But I do believe that we, as an organisation, could engage more in collaborations with researchers from other domains. We can benefit from the social sciences, such as criminologists, just as much as the Outbreak Management Team for COVID-19 benefitted from putting behavioural scientists next to medical expertise. This may foster refreshing new insights for the significant challenges we face.

Rotterdam Court of Audit

Marjolein van Asselt

I often describe myself as an experienced researcher-administrator. And I enjoy research that not only is of benefit to society, but that is essential to society. With my background in engineering, I have an above average interest in technology, which comes in handy in safety & security matters. But it' certainly not only engineers at the Court of Audit. Sociologists, anthropologists, historians, public administration specialists, criminologists – you can pretty much have any scientific background and work at the municipal Court of Audit.

National Police

Sven Hamelink

As mentioned before, we have been closely collaborating with universities and knowledge institutions that are rooted in the applied sciences. And the insights from experts such as data scientists and engineers are especially valuable when it comes to technology. Furthermore, the rapid societal developments will transform our work processes. That is a major driver for us to increase overall "tech awareness". It means that, next to even more engineers, we also need other scientists who are tech-savvy and who have an affinity for ICT. To me, diversifying our expertise is a prerequisite.

RIVM

Jaco Westra

I studied physical chemistry and then entered the field of safety of hazardous substances. This involved both substantive work and policy work. In my current role, I no longer need to fully understand all the technical details. But to effectively manage the research, I need to grasp the main concepts. It helps to have a background in the exact sciences as it prevents one from getting lost in the world of toxicologists and chemists.

text Ilse Oosterlaken & researchers **photo** INGimage

Engineering for human security

We face exacerbating climate change. Excessive precipitation and heat waves will become more frequent in the coming decades. These could lead to shortages of food, water and energy and subsequently to conflicts and displacement. By 2030, hundreds of millions of people could be leaving their homes searching for (more) human security. These social disruptions could further reduce our resilience to climate change. TU Delft's new Climate Safety & Security Centre (CASS), led by Behnam Taebi, will address this human security challenge in times of climate change, focusing on the role of technology. For instance, modern waterworks can be vulnerable to cyber-attacks, and new technologies allow us to manipulate cloud formation on a large scale. Each technology brings both opportunities and risks. These must be considered from the outset in the development and application of technology, with attention to the relevant social and ethical issues.

With the goal of ensuring the safety and well-being of employees, safety culture is certainly a matter for organisations. But developing a strong safety culture is a complex process that requires an integrated approach. Two safety experts from different fields agree that collaboration between science and the workplace is essential.

text Heather Montague

Marcel Vervoort and Karolien van Nunen discuss:

Is safety culture a matter for the workplace, not science?

Behaviour and risk assessment

As someone who deals with safety in the workplace, Marcel Vervoort, Safety Engineer & Occupational Hygienist at TU Delft's Reactor Institute, sees a strong connection between safety culture and behaviour. "Yet we don't really have a good grip on how personal and group behaviour and the psychological mind can be influenced in recognising and anticipating risks. For example, what has a negative or positive influence on safety behaviour within a group? I think research into such questions can have a very important role in safety culture development."

Doing science at a high level means not always being aware of the risks entailed. "With scientific projects, one of the most important safety issues is that researchers often use and develop new and unexplored techniques or substances," says Vervoort. He notes that doing risk assessments at the beginning of a project, even as part of a scientific proposal, is valuable. "In my experience, the implementation of risk assessment for scientific setups has a positive influence on safety behaviour. If risk assessment is thoroughly implemented and supported by the management, the safety culture develops in a positive manner."

Evidence-based cooperation

An adequate safety culture is much more than the absence of having accidents, explains Karolien van Nunen, Assistant Professor in Safety & Security Science at TU Delft. "It's about how safe people feel themselves, their perceptions, their attitudes towards safety. Furthermore, individual behaviour is an important aspect of safety culture, but safety culture entails much more. Also the specific characteristics of an organisation and the context in which this behaviour takes place play an important role. Acknowledging the complexity of safety culture is needed."

There are many tools, methods, and approaches being used by practitioners to assess and improve organisational safety culture, but often they are not evidence-based. It is the role of academia to guarantee that they become evidence based, she says. But that's not the only issue, according to her. "There is too much academic research that remains too abstract or too high-level. It is the role of the people in the field to safeguard that research output is valuable and usable in the workplace. In my research on safety culture, I advocate the importance of very close cooperation between scientists and practitioners. Understanding, assessing, and improving safety culture is not something that can be done by isolated stakeholders. Cooperation between scientists and organisations is key."

Zeki Erkin

During his Bachelor's and Master's at the Istanbul University of Technology, Zeki Erkin did what he loved most, in his own words, he was "playing with numbers and number theory. My BA end-of-year project was about zero-knowledge proofs and secret sharing, two concepts that were quite unusual and not much in practice. I was also interested in steganography, and the idea of hiding communication from the naked eye. The project covered subjects of secrecy, trust and sharing, and I loved it. It certainly paved the way for my work in security and privacy."

While looking for my PhD subject I came across Professor Inald Lagendijk, who was already combining security and privacy in his work. It was a perfect match. From my perspective as a researcher looking into the different components of private and secure communication, I found myself in a rich environment of many variants at TU Delft.

"All my life, I really cared about the individual's rights. The right to privacy is contained in the Universal Declaration of Human Rights and everyone agrees that individual personal privacy and full control of it is essential. But in the face of a society dependent on high-density information technology and electronic media, it is becoming increasingly difficult to implement this human right in digital systems. Cryptography offers a way to protect sensitive data and protect individual privacy."

"Back in 2002, when I was a computer scientist, the subject of privacy was not a point of major concern in business. The emphasis was on security, especially concerning products or services. But even then, two decades ago, I already believed it was our role as scientists to provide the tools and means in digital systems for everyone to be able to protect their privacy. Because if we weren't going to do this on behalf of citizens, then who would?"

"In the last ten years, there have been many changes in the field. Privacy has been promoted from lesser status as an add-on workshop at security conferences, to the headliner at privacy conferences and symposiums. The initial resistance that I often faced in getting funding for our research, was linked to the elevated status of digital security at the time. When a manager suggested that I switch subjects to get grants and apply to the security field "because privacy isn't getting you anywhere", I strongly disagreed! Research needs to look further and aim for the betterment of society. We should avoid acting with an 'industry mindset' which is short-term oriented. Let's look at five or ten or fifteen-year projects. I think long-term academic projects are vital, but who will do it?"

In 2018 there was a light at the end of the tunnel and that light was called GDPR. The EU recognised an individual right to control one's own data. People started to take notice of privacy. Compliance was the buzzword of the year. But basic compliance was not enough. The big change was when major companies realised they could collect and analyse data if they collaborated using cryptography. "It's a very positive sign that after two decades, our privacy research is paying off."

Zeki believes an effective framework for security and privacy requires three things; The first is education and awareness of risks and rights, starting with basic training in privacy and security knowledge for every child at school. Secondly, authorities need to set solid laws and regulations in place. "Thirdly, we need technical solutions, but companies are still somewhat reluctant and unwilling to be the first to take the leap because privacy protection requires overhead. And this is where I can play my part, together with colleagues worldwide."

Zeki Erkin is an associate professor in the Cyber Security Group, at TU Delft. His research is on Privacy Enhancing Technologies, particularly on Computational Privacy. He is in the steering Committee of Cyber Security Next Generation (CSng) and vice-chair for ACCSS.

text Helen Hartmann **illustration** De Zagerij ontwerpbureau

“Engineers must learn to talk about ethics”

Twenty minutes into the conversation, Bartolomeus Häussling Löwgren says: “Engineers tend to run away from ethical questions. They are focused on technology and prefer mathematical models with clear outcomes.” It needs to change, in his opinion. “We live in a society where questions like these need answers from everyone involved. Engineers must learn to talk about ethics.”

text Marco Visscher
photos De Zagerij ontwerpbureau

With thirteen other young researchers, Bartolomeus looks back on the three-day Safe by Design course for PhD students and postdocs. During lunch, they discussed the subject matter in the cool temperature of the reception area of TU Delft in The Hague. It’s early June and 30 degrees Celsius, and that day marks the beginning of a heat wave. The door to the Bezuidenhoutseweg is open. The questions about ethics which Bartolomeus raises closely relate to the course and spark a discussion. Safe for how long? Safe for whom exactly? One participant suggests that safety is often user-focused and should be more about environmental protection. Another participant wonders which values we can use to measure safety.
As it turns out, it has become clear to the researchers how important it is to consider safety on time, concludes Abhishek Dhyani. “Usually, there is a lot of emphasis placed on the choice of materials,” he says, “but here, there is a much broader scope.”
In other words: yes, the course is useful, gives food for thought and provides ideas for research.

"Dealing with uncertainty is a recurring challenge that everyone still needs to solve"

Dealing with uncertainty

Behnam Taebi emphasises the informal nature of the session. He leads the discussion as scientific director of the TU Delft Safety & Security Institute. "We're especially keen to get an honest evaluation and suggestions for improvements."

The participants honour Taebi's invitation for critical reflection. One young researcher finds the teaching material challenging to apply because her research focuses on medical implants. Human tissue, by definition, reacts unpredictably to foreign substances, she says, making a safety analysis almost impossible. Another participant questions the actual relevance of all the reflections because the current economic system prioritises financial interests, ergo; safety will always lose out to monetary gain.

Dealing with uncertainty is a recurring challenge that everyone still needs to solve. Sometimes data is insufficient for adequately assessing risks, according to Erin van Rheenen. Sometimes the simulation in the lab is too far removed from the chaos of the real world, says Abhishek, who researches autonomous ships. And then what? They ask.

Julieta Bolaños Arriola nods. How much uncertainty is acceptable, she asks. And: how do you talk to designers about these kinds of uncertainties?

The next edition of the course can explore these questions in more detail, Taebi concludes.

The human factor

Erin is researching the possibilities of hydrogen carriers on ships. "Often the course discussed whether there are alternatives to hazardous or harmful substances," she says, "but in this case, there is only a minimal number of chemicals with the properties needed. In that case, the usual risk analysis falls short."

And then, says Erin, there is the interaction between people and substances. How do the staff on board deal with it? And the port employees? "I don't know how to incorporate the human factor."

Ah, yes, the people. It's something that Fernando Ramonet Marques also brings up. "Engineers concentrate on concrete things or processes," he says, "but: what about the humans?"

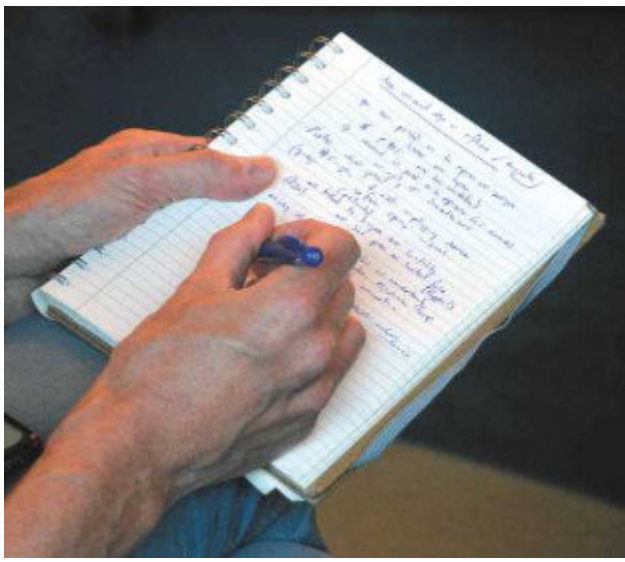
Fernando discusses the need for a division of responsibilities to ensure safety and sustainability. The consensus within the circle of researchers is that everyone is responsible, but also, in practice, 'everyone' often means: no one. Finally, the researchers agree that each individual takes responsibility for their work.

> “The consensus is that everyone is responsible, but also, in practice, ‘everyone’ often means: no one”

Taebi adds that in recent years, safety has been a theme that concerns more and more people. Initially, car designers mainly focussed on the safety of the occupants. Later, they considered the safety of those in the other car involved in a possible collision. Nowadays, they also take cyclists and pedestrians into account more than ever.
At the other end of the process, there may be an element of tunnel vision for the end user. For example, if there is confusion about the safety of new technology. “Our perception of security depends on our knowledge,” says Shachi Shanbhag. “Engineers might understand new technology, but the general public can still misunderstand it. For some, the technical jargon is simply incomprehensible. As a result, the technology might be perfectly safe but regarded as unsafe by an uninformed public.”
Shachi’s comment prompts reflection on whether it matters if you design for actual safety or just the perception of safety. Perhaps, someone suggests, in this respect, it is a good step that the United Nations International Maritime Organization (IMO) is making a switch from precise regulations (with minimum dimensions of a door, for example) to more general goal-based standards (the door must be safe). "It’s more difficult to work with, but it challenges engineers to explain safety better."

Interest in repair

The young researchers are visibly involved in such theoretical reflections and show a far-reaching interest in sustainability. Julieta is researching the possibilities of a so-called circular economy, in which, for example, new raw materials are reduced, and waste is reused in a closed cycle. “The circular economy is radically different from the linear economy,” says Julieta, “because there are currently no financial incentives to repair and recycle, for example, due to cheap production.”
She has noticed that conversations about the circular transition attract civil servants, entrepreneurs and social organisations. Engineers remain on the sidelines for now, despite “the adaptation to a system with multiple life cycles and an emphasis on repair having consequences for design and safety”, according to Julieta.
Taebi challenges her to be more concrete in her argument. “Many products are not designed for home repairs,” explains Julieta. “Manufacturers claim it’s due to regulations and legislation that instruct them to protect the safety of their customers. And indeed, that’s a legitimate point. A

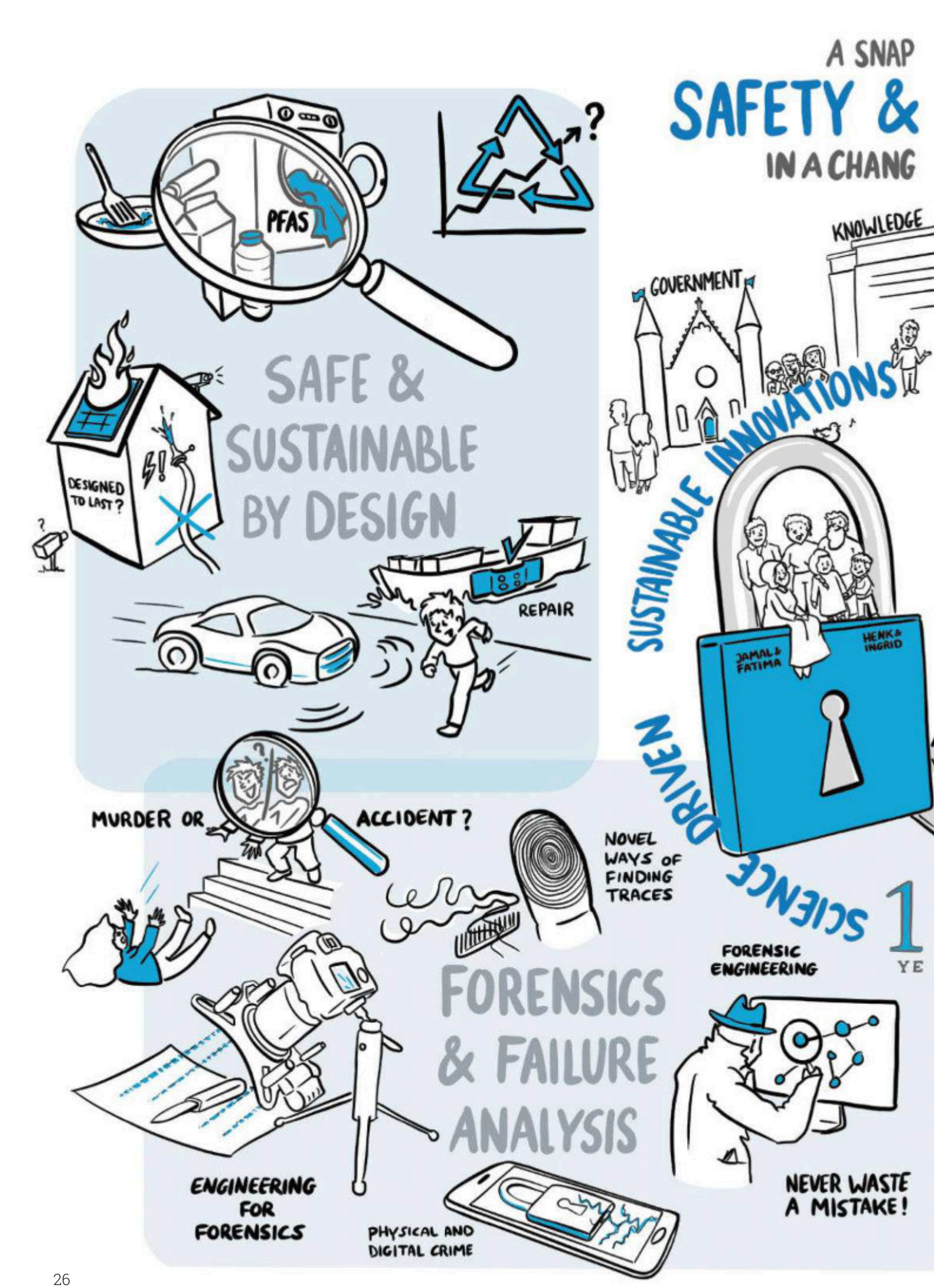


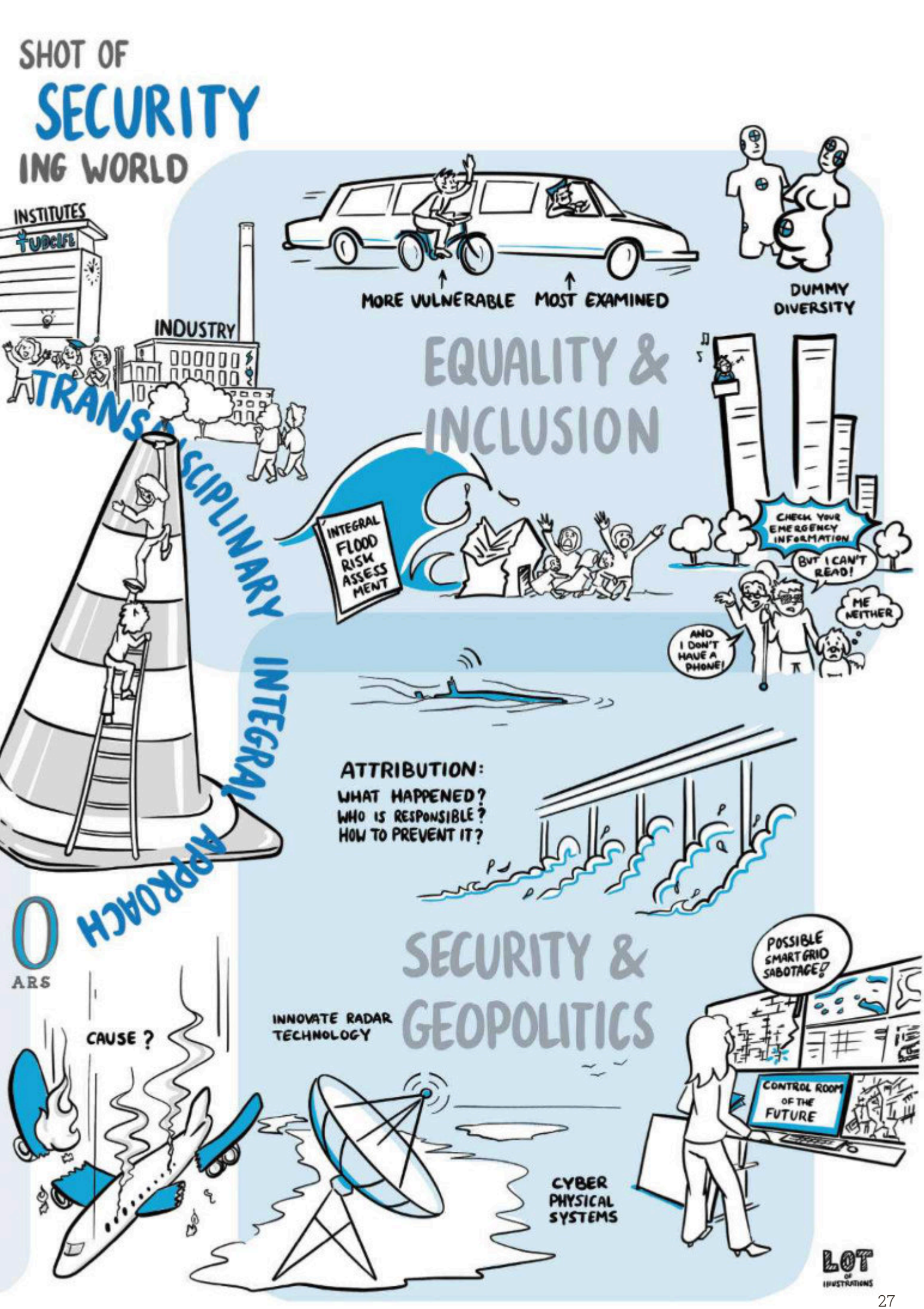
broken coffee machine means a combination of electricity, water and chemicals. Is that combination dangerous? Does everyone understand that you must first pull the plug out of the socket? Is everyone capable of doing repairs themselves?"
In any case, a better emphasis on recovery rather than production is called for, Evelien Scheffers adds. To illustrate this, she refers to her department at TU Delft called Ship Design, Production & Operation. Is there really no room for the word Repair in that title?"

In twenty years
The evaluation ends with an open question: where do you hope the Safe (& Sustainable) by Design field will be in about twenty years? "A world without accidents," jokes Anna Flavia de Souza Silva. "Universal standards," suggests Stratos Mikropoulos. Abhishek describes a kind of global handbook for safety.
Evelien has an entirely different picture of the ideal future. She hopes the field will no longer exist. She explains, "It means that ideas about safety and sustainability would be fully integrated into design processes and no longer have to be offered separately."

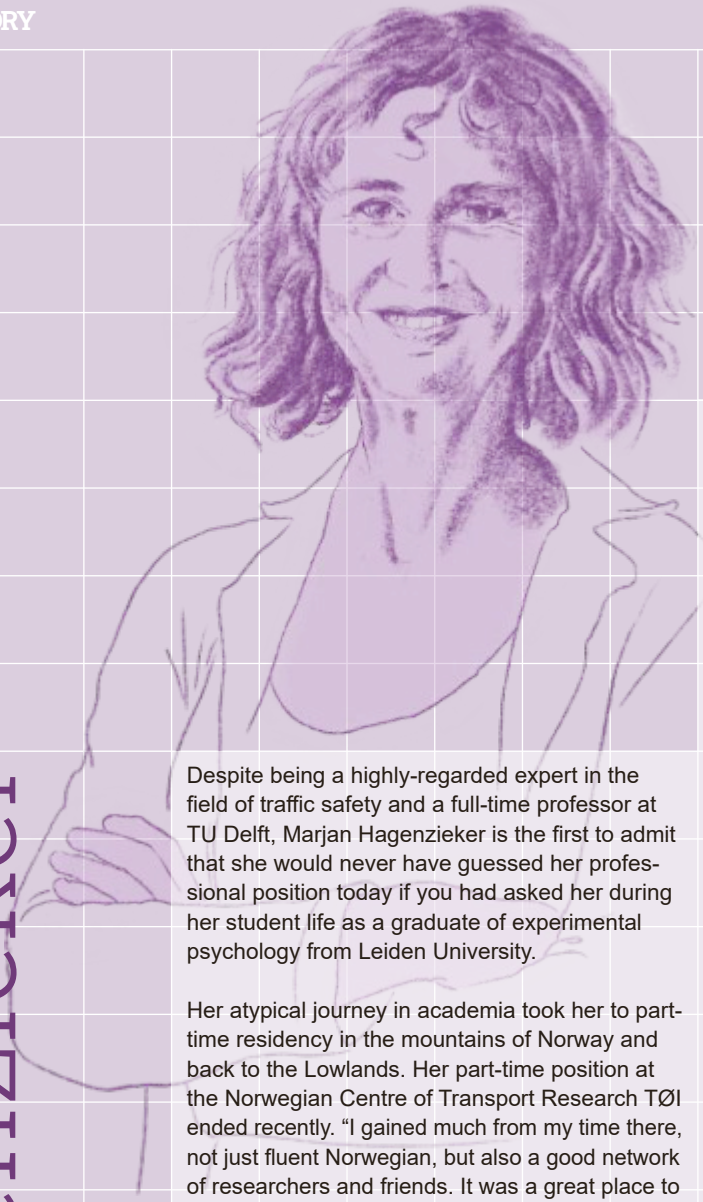
Safe by design
A clean and safe world. Safe products, materials and processes, without risks for people and the environment. Now, later, and in the far future. We achieve this by considering safety from the very beginning of every product and process development. In collaboration with TU Delft, among others, the Ministry of Infrastructure and Water Management is shaping the Safe by Design approach and policy through joint research and innovation. Research topics do not only concern materials, chemicals and products, but also cover ethics and awareness.

About this course
The TU Delft Safety & Security Institute runs an annual 3-day interdisciplinary course, Safe by Design (SbD). Sustainability is also included, or S(S)bD. This approach shifts our focus on safety into the earliest stages of design and extends it by considering safety alongside other essential values. The design and implementation of the course is a collaboration between TU Delft, Wageningen University & Research, Utrecht University and RIVM. The course is open to young researchers (PhD students and postdocs) from Dutch universities.


A SNAP
SAFETY &
IN A CHANG
PFAS
?
SAFE &
SUSTAINABLE
BY DESIGN
DESIGNED TO LAST?
REPAIR
KNOWLEDGE
GOVERNMENT
SUSTAINABLE INNOVATIONS
JAMAL & FATIMA
HENK & INGRID
SCIENCE DRIVEN
1
YE
MURDER OR ACCIDENT?
NOVEL WAYS OF FINDING TRACES
FORENSIC ENGINEERING
FORENSICS
& FAILURE
ANALYSIS
ENGINEERING FOR FORENSICS
PHYSICAL AND DIGITAL CRIME
NEVER WASTE A MISTAKE!


SHOT OF
SECURITY
ING WORLD
INSTITUTES
TUDELFT
INDUSTRY
TRANSDISCIPLINARY
INTEGRAL APPROACH
MORE VULNERABLE
MOST EXAMINED
DUMMY DIVERSITY
EQUALITY & INCLUSION
INTEGRAL FLOOD RISK ASSESSMENT
CHECK YOUR EMERGENCY INFORMATION
BUT I CAN'T READ!
ME NEITHER
AND I DON'T HAVE A PHONE!
ATTRIBUTION:
WHAT HAPPENED?
WHO IS RESPONSIBLE?
HOW TO PREVENT IT?
0
ARS
CAUSE ?
INNOVATE RADAR TECHNOLOGY
SECURITY & GEOPOLITICS
POSSIBLE SMART GRID SABOTAGE?
CONTROL ROOM OF THE FUTURE
CYBER PHYSICAL SYSTEMS
LOT OF ILLUSTRATIONS

Marjan Hagenzieker



Despite being a highly-regarded expert in the field of traffic safety and a full-time professor at TU Delft, Marjan Hagenzieker is the first to admit that she would never have guessed her professional position today if you had asked her during her student life as a graduate of experimental psychology from Leiden University.

Her atypical journey in academia took her to part-time residency in the mountains of Norway and back to the Lowlands. Her part-time position at the Norwegian Centre of Transport Research TØI ended recently. “I gained much from my time there, not just fluent Norwegian, but also a good network of researchers and friends. It was a great place to live and work, but I see my colleagues less since COVID introduced popular work-from-home habits. I miss the interaction.”

Marjan is a pioneer of research into automated driving systems from the cyclist’s perspective. Much to the amusement of her friends and colleagues in Norway, Marjan is not an avid cyclist. “Yes, I know it’s quite funny. I’m a cyclist expert who doesn’t like to cycle! I prefer to walk and enjoy the pace of walking and taking in my environment. I use my bike for convenience. Luckily, I don’t need to be a cycling fanatic to be an expert in my field.”

“In traffic, I am a cautious driver and cyclist. I’m very risk-aversive, and I have a fear of heights. Maybe that’s why I came to Norway. To challenge myself with all these mountains! I’m certainly not a daredevil, except perhaps in my mind! I do have an innate drive to explore within my field. So, in the past years, I have been delving into research on the automated vehicle: Will it make traffic safer? What does it mean for the driver and, even more so, what about other road users, i.e. cyclists and pedestrians? These questions were largely unexplored territory back in 2016, and now it’s more common to include other road users in research rather than the traditional narrative of the driver.

“Looking back, it might look like coincidences led me here. I chose elective courses at Delft University during my Master’s because this was where people were actually making things (as opposed to my research field, which was further away from real-life applications). You wouldn’t typically find a psychology student in those subjects back then. And there were fewer women in that environment. I wanted to try something different and was a bit rebellious. Another factor was the high unemployment rate in the 1980s, especially for psychologists. I spotted a vacancy for a temporary job at SWOV (Institute for Road Safety Research) in the newspaper. The position required a social and behavioural sciences background, and I applied even though it was temporary. I got the job and ended up staying for many years.”

A combination of curiosity and daring paved the way for Marjan’s professional journey rather than a string of coincidences. “Now, I have only been a professor for nearly ten years, which is not long for someone my age. But my career was not preplanned; becoming a professor sort of came out of the blue. I made some decisions that worked out. But it still feels like it all happened naturally. I am really enjoying finding my place on this journey.”

Marjan Hagenzieker is professor at TU Delft. She graduated in experimental psychology and received her Doctorate (PhD) at Leiden University. Her research and education activities focus on the road safety effects of the transport system, with particular interest in road user behaviour aspects. Research topics include distraction in traffic, the safety of vulnerable road users (e.g. elderly, bicyclists), road user interactions with road infrastructure, in-vehicle technology, and automated driving systems.

text Helen Hartmann **illustration** De Zagerij ontwerpbureau

The TU Delft Approach to Forensic Engineering

“Don’t let **good failures** go to waste!”

photo Onderzoeksraad voor Veiligheid

Safety science and practice are all about preventing harmful incidents. But sometimes things still go wrong, unfortunately; a plane may crash, a bridge may collapse, or a medical device may give people an infection. Often, such events are human tragedies that raise many questions about how and why they happened. This is where a forensic engineer enters the scene. We talk about this with Michiel Schuurman, one of the three founding fathers of the TU Delft approach to this field of investigation.

Michiel, are you the Sherlock Holmes of TU Delft?
"Well, forensic engineers do carry out investigations, like Sherlock Holmes. But murder is a unique and one-off event, and Holmes stops after answering the 'whodunnit question'. In contrast, we are not just interested in the causes of an incident, but especially in how it could be prevented in the future, for example by a better technical design or different safety measures. So, any conclusion about causes should have recommendations accompanying it. There is a lot at stake, so it is important to be thorough and arrive at valid conclusions."

Is this where the TU Delft approach comes in?
"Exactly. It is based on best practices of forensic investigations in three different fields: aerospace engineering, civil engineering and biomechanical engineering. Karel Terwel started the challenge of creating the TU Delft approach. Arjo Loeve and I brought our knowledge from the other two research fields to further develop it. There are numerous methods and models to explain possible causes of accidents, ranging from failing materials to human errors. However, we felt a systematic approach was needed to ensure nothing was missed or overlooked. Using our methods ensures you look at all the possible causes of failure."

And has the approach already been put into practice?
"Certainly! A good example is the collapse of the roof of the Dutch AZ (soccer) stadium on August 10th, 2019. Forensic investigation was carried out into the failure mode, and a report was published with conclusions on the cause of the collapse. The Dutch Safety Board wanted to determine the validity and completeness of that investigation. Another consulting company was commissioned, and they decided to use our TU Delft Approach. Following our step-by-step process, they arrived at recommendations to consider other possible scenarios and failure mode(s) that were not considered in the initial forensic investigation."

Fortunately, such accidents are rare. Is there a demand for forensic engineers?
"Judging by the success of our free online course or MOOC on the topic, there is. We have run it since 2017, with 3000-4000 students each year from over 145 countries. The course exposes you not only to the TU Delft mindset to investigate incidents to prevent them in the future, but also confronts you with a wide range of things that could go wrong. This helps to create safety awareness. That is why, I suppose, the course is also being used to train hospital staff and other professionals."

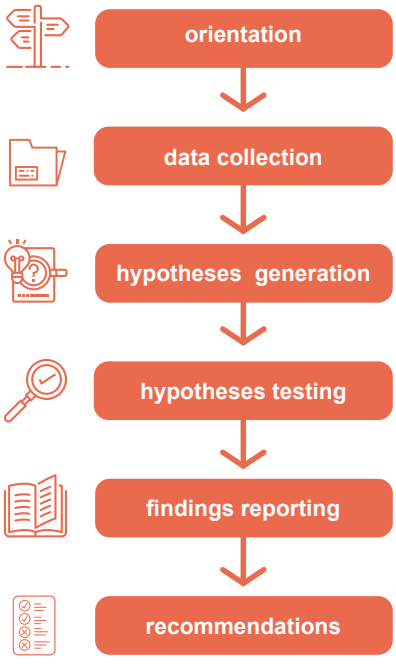
THE TU Delft APPROACH

Patients get an infection from a medical device. A plane crashes. A building collapses. That calls for an investigation by a forensic engineer:
- What happened?
- What caused it to happen?
- How could it have been avoided?
- How could the technical system be improved to avoid such failures in the future?

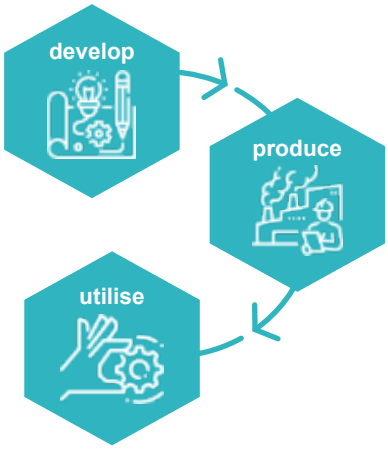
Here's our method for such an investigation:

Developed by Karel Terwel, Michiel Schuurman & Arjo Loeve

Use a standard investigative approach



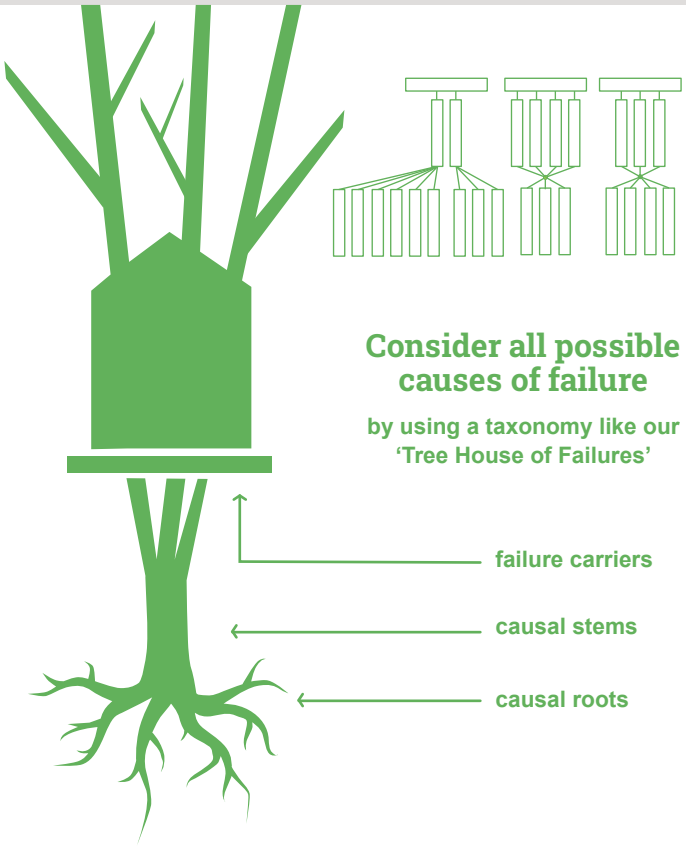
Consider all phases of the product lifecycle

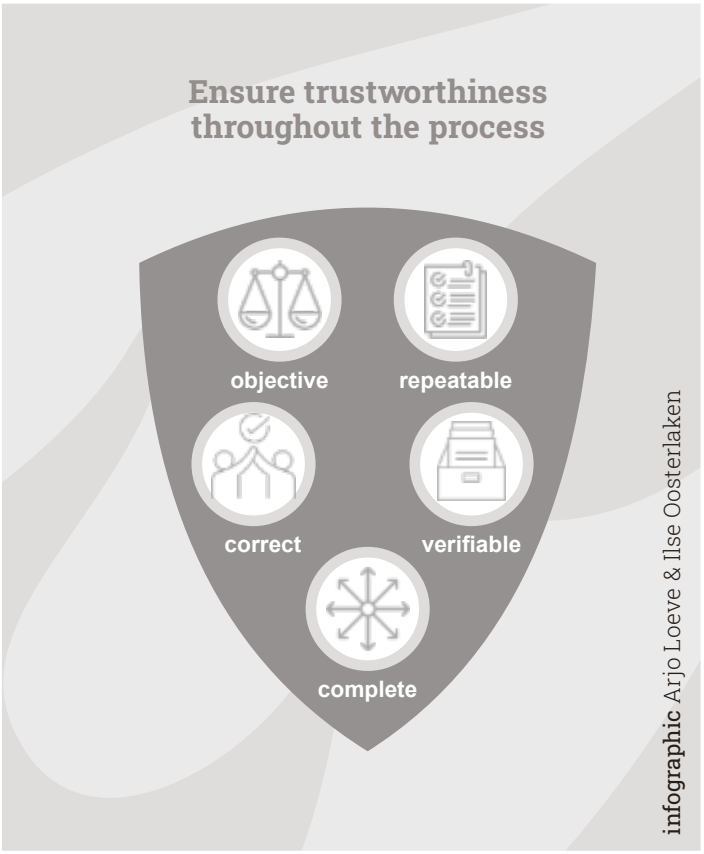


And what about TU Delft students?
"TU Delft is educating the next generation of engineers; in my view, they could all benefit from learning to learn from failures. As I like to say to them: 'Don't let good failures go to waste!' Reading a book and attending lectures is not enough for that. I want them to get their hands dirty, so to speak. At the Faculty of Aerospace Engineering, forensic engineering is used in the context of aircraft accidents. For the final exam of my forensic engineering course, I create a mock crash site somewhere on the campus. Groups of students are tasked to investigate and report on the event. Several students who have taken the course have become safety investigators at airlines and aeroplane manufacturers."

What does the future hold for forensic engineering at TU Delft?
"Karel, Arjo and I intend to introduce more interactive assignments in the MOOC. Currently, we are working hard on a project that will allow students to experience the Delft approach in an investigation. The present material can also be used to integrate forensic engineering with other courses taught at TU Delft. It would also be great to see more embedded research where TU researchers work with the police and other government agencies on real-life challenges that they face to keep society safe and secure."

Michiel Schuurman is assistant professor at the Structural Integrity and Composites group of the TU Delft Faculty of Aerospace Engineering.





infographic Arjo Loeve & Ilse Oosterlaken

The Control Room of the Future

If it were not for the futuristic blue glow of light, you would not suspect anything special is happening in this room – just some computer screens along a wall. But nothing could be further from the truth. This is the Control Room of the Future (CRoF) technology centre, an innovation hub developed by Alex Stefanov for future power grid technologies. It allows researchers to simulate how disruptions like lightning strikes or cyber-attacks affect the Dutch power grid. Blackouts are nightmares for the energy sector, desperately seeking ways to keep the heavily loaded power system stable and secure. In the CRoF, researchers work on detecting, preventing, and mitigating cyber-attacks using AI and computational intelligence techniques and building cyber-physical system resiliency. An important research pillar is privacy in smart grids, led by Zekeriya Erkin. His team is investigating how energy system management can use the data from smart meters in people's homes without violating their privacy. The future will tell... or rather, it's getting a little closer here.

text Ilse Oosterlaken & researchers **photo** Willem de Kam

How do you keep transportation safe despite, or perhaps with, increasing automation and AI (Artificial Intelligence) usage? How do you balance safety against the need to shift focus to sustainability? What new engineering approaches are needed to deal with the rapid developments in the transportation sector? We asked Rob Goverde (rail), René Alderliesten (aviation) and Joost de Winter (road) to reflect on the challenges and opportunities in their respective fields. And what can different transport modes learn from each other? With that question in mind, we end with Eleonore Papadimitriou, who looks at all transport modes by fusing concepts and methods from various disciplines, for example, engineering, ethics, human factors, safety science, statistical modelling, data science, and health. What new insights does this approach bring?

photos INGimage, Pixabay

Safety & security in a transport sector **on the move**

Joost de Winter is Professor in Cognitive Human-Robot Interaction at the Department of Cognitive Robotics (Faculty of Mechanical, Maritime & Materials Engineering), where he works amongst others on driving simulation and automated driving.

René Alderliesten is an Associate Professor in Aerospace Structures and Materials at the Faculty of Aerospace Engineering and section leader of the Structural Integrity and Composites research group within that faculty.

Rob Goverde is Professor of Railway Traffic Management & Operations at the Department of Transport & Planning (Faculty of Civil Engineering & Geosciences) and Director of the Digital Rail Traffic Lab.

Eleonora Papadimitriou is Associate Professor of Transport Safety at the Section of Safety & Security Science (Faculty of Technology, Policy & Management), where she is part of an interdisciplinary team with Pieter van Gelder, Amir Pooyan Afghari and Oscar Oviedo-Trespalacios.

“It is hardly responsible to let a human drive among pedestrians and cyclists without the latest automation systems”

Joost de Winter

Road

What is your research focus?
“My research focuses on the interaction between technology and humans. We investigate how automated driving systems, drivers inside cars, and cyclists and pedestrians outside cars (should) behave and communicate. To provide an illustrative research question: Should an automated vehicle show stereotypical automated driving behaviour by strictly maintaining the centre of the lane, or should it rather display certain human-like behaviours?”

What is the main challenge of automation in your field?
“On the one hand, humans make so many mistakes in traffic that one could wonder why we do not place a much higher priority on introducing automation. It is hardly responsible to let a human drive among pedestrians and cyclists without the latest automation systems.

On the other hand, we must acknowledge that not all technology works well or will be accepted. In practice, separate subsystems are being rolled out instead of full automation. Some of such systems, such as lane-keeping warning/support systems, can annoy the driver. The driver may, therefore, turn off such systems, which means that the potential safety benefits are not realised. We should not operate with a technocentric mindset, introducing automation just because we can. To further illustrate this, one of my PhD students is researching human-machine interfaces for future bicycles. However, her interviews in the Netherlands and Norway showed that many cyclists are not particularly keen on certain innovations; they like the simplicity of the bicycle.

The challenge is to develop a coherent vision of the way forward. How do you strike the right balance between acceptance and effectiveness? And should we strive for full or situation-specific automated driving or shared control where the driver remains continuously involved in the control loop?

What is the role of Artificial Intelligence (AI) in your field?
“AI is involved in all cases where sensor information is read and translated into an action of the automated vehicle or feedback to drivers or road users. The recent developments in linguistic models, of which ChatGPT is an example, are particularly interesting because language can form a suitable way to communicate with humans. One of the things we are looking at are smart dashcams: can we translate the images from the dashcam into an explanation of the traffic situation? Could such technology be a good coach or evaluator of manual driving behaviour during driving license tests?”

What role do other societal values, such as sustainability or inclusivity, have in your safety research?
“A point that I would like to mention is that of inequality: Regarding traffic fatalities in the Netherlands, we have reached a point where most victims are those outside vehicles rather than those inside them. The wealthiest in society can presumably afford the largest/heaviest cars equipped with the latest automation technology. My research hopes to ensure that the focus is not solely on the comfort of the driver of the (automated) car, but that there is a primary emphasis on improving the safety of vulnerable road users.”

Air

What is your research focus?
"My research focuses on improving means to comply with the rules and regulations for the safety of materials and structures. I do this by developing new methodologies that utilise physics, process monitoring, and simulation to replace testing and large experimental datasets. Currently, structural certification is based on performing sufficient tests and using interpolations to make predictions. With the complexity of technologies increasing, this way of working delays innovation. For example, introducing fibre metal laminates and carbon fibre reinforced composites in primary aircraft structures took three decades."

What is the main challenge of automation in your field?
"We see three ways to make faster certification possible, especially when they are developed in combination. First, physical principles are introduced to replace the test data interpolation in prediction methodologies. This will make them more intuitive and simpler, which will hopefully put a stop to the current proliferation of prediction models. Secondly, with proper process monitoring during and after manufacturing, the quality and state of products can be demonstrated while improving the input quality of prediction models. Finally, AI can contribute. The big challenge is acceptance, both by industry and by airworthiness authorities."

What is the role of Artificial Intelligence in your field?
"AI is emerging in certification, for example, the European airworthiness authority has recently issued guidelines for AI in certification. AI can improve and accelerate quality assessment after production and potentially improve the demonstration of continued airworthiness of structures in operation (continuous structural integrity). That latter aspect, however, seems still in its infancy. Demonstrating that new technologies have an equivalent level of safety to existing ones requires large data sets to accurately describe and predict the behaviour of materials and structures unless we find means to make AI methods lean and explainable. AI could be made more efficient by incorporating physics to reduce the fitting and data size requirements."

What role do other societal values, such as sustainability or inclusivity, have in your safety research?
"Safety in aviation is considered a non-negotiable boundary condition. Sustainability is, of course, also important. But any innovation, whether it is targeting sustainability or not, should comply with the safety rules. These rules are developed based on past practice and technologies, requiring a continuous assessment of whether current rules are sufficient for new ideas and innovations or whether new rules are to be formulated.

I mentioned before that it took three decades to get fibre metal laminates and carbon fibre approved in primary structures. Current innovations, specifically those targeting carbon-neutral aviation, will take even more time if the same concepts for certification remain adopted. The emission targets of 2050 can only be met when certification processes are accelerated. The most obvious solution is developing new concepts to demonstrate compliance to current rules."

René Alderliesten

"Innovations targeting carbon neutral aviation will take more than three decades if we don't change how we certify the safety of materials and structures"

“Railway transport is the most sustainable and safest mode of transport”

Rob Goverde

Rail

What is your research focus?
“My research is about improving the performance and automation of the integrated railway traffic system, which includes the planning and controlling of individual train services and their interactions on the railway network. The capacity of the railways must increase significantly to accommodate the growing demand while also realising high reliability and lower energy consumption and costs. Digital technology can facilitate the expected growth through a mix of radio-based communication and train control (ERTMS, European Rail Traffic Management System), Automatic Train Operation (ATO), and Traffic Management Systems.”

What is the main challenge of automation?
“Digitalisation and automation require a revision of railway planning and management. In particular, the various elements of the railway traffic system must be better aligned, including the data and models for timetabling, traffic management, train operation, and railway signalling. This will result in safe, conflict-free, reliable and energy-efficient train operation over dense networks.

Safety and control systems are separated in the railways, with control systems being supervised or constrained by the safety systems. Moreover, both the infrastructure and the trains are controlled, by which the safety and control systems each have trackside and onboard components that all must operate smoothly together. The safety systems are already highly automated, although they are being replaced by modern digital systems such as ERTMS. The control/management systems are still highly manually operated.

Much research is devoted to automated control and management systems, such as automatic train operation (ATO) and automatic conflict detection and resolution in rail traffic management. The scale of the railway networks is a particular issue when migrating to new systems, as well as the interoperability of trackside and onboard systems. ATO has several Grades of Automation, from automatic supervision functions to fully automated train operation. In the latter case of driverless trains, the safety tasks of drivers, like obstacle detection, must also be automated.

Another challenge of automation in the Railways is the availability of consistent and accurate data all over the network and even cross-border.”

What is the role of Artificial Intelligence in your field?
“AI in the Railways is still limited. Most AI applications are found in asset management such as preventive maintenance and defect detection. For operations, AI research focuses on delay prediction and obstacle detection on or near tracks. For safety-critical functions, transparency, explainability, and trustworthiness of AI solutions are big issues. Therefore, research for safety-related functions focuses on AI support to traditional methods.”

What role do other societal values, such as sustainability or inclusivity, have in your safety research?
“Railway transport is the most sustainable mode of transport and plays an increasing role in the accessibility of cities, livability within cities, and sustainable (inter)national connections. Rail is also the safest mode of transport, with safety systems designed according to failsafe principles and the highest Safety Integrity Level. Railway digitalisation with ATO and advanced traffic management systems will optimise energy-efficient train operation, while safety is guaranteed with the new generation of radio-based railway signalling (ERTMS).”

Transport

What is your research focus?
"Our multidisciplinary transport safety team uses perspectives from all transport modes and from different disciplines to develop new insights into transport safety. For example, we look at complex urban settings, where smart applications, technologies and new transport modes (like e-scooters), rapidly penetrate an already 'chaotic' traffic system.

The 'safe system' concept is the backbone of our interdisciplinary approach. It entails looking into the interaction between drivers/operators, vehicles/vessels, infrastructure, policy, technology and environment – and the responsibilities of each actor in that system. We strongly focus on developing and using robust econometric, probabilistic and holistic methods of risk analysis, which can accommodate the complexity of today's transport systems and the role of people in them."

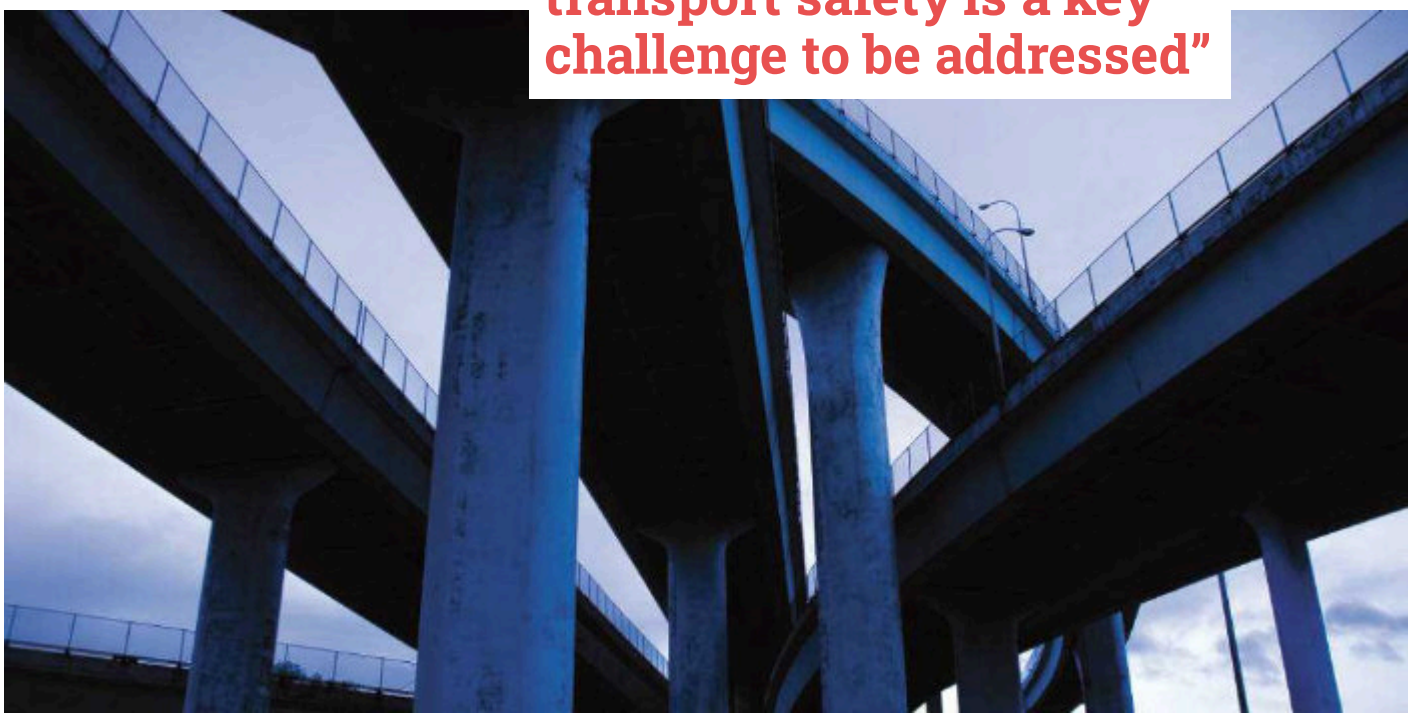
What is the main challenge of automation?
"In aviation, automation has been a reality for decades, yet it is well-known that human-system interaction is becoming increasingly complex despite important safety improvements. Automation on the road and in the maritime sector is currently emerging but without any systematic transfer of knowledge from the aviation sector. All parties involved would benefit from joint knowledge development. For example, how can humans constructively interact with the highly complex systems of the future when the human role becomes more and more limited? How can we keep a human operator in the loop and situation-aware so that they can take control of the system if it fails? To what extent should control be shared between humans and AI in the vehicle/vessel or remotely controlled operations?"

What is the role of Artificial Intelligence in your field?
"The justice dimension of AI usage in engineering and technology applications for transport safety is a key challenge to be addressed. Recently, we received a new grant for an interdisciplinary project on 'AI for vision zero in road safety' - vision zero is the EU strategy to eliminate traffic fatalities by the year 2050. We will investigate the ethical dimensions, human factors, and engineering and data science innovations that must come together for fair and impactful AI solutions for road risk. We will for instance investigate what AI solutions can be applied in less automation-ready countries. And how AI can become more efficient yet privacy-sensitive to timely detect and protect all types of road users in urban areas."

What role do other societal values, such as sustainability or inclusivity, have in your safety research?
"Many new technologies or features to improve safety are not accessible to or affordable for vulnerable populations. Think of low-income households, young people, older people, low-to-middle-income countries. How can we make these technologies equitable and inclusive to those most affected by transport risks? Also, safety must be ensured within the complex transport system to promote sustainable transport modes like cycling and walking. Our research demonstrates that safety and other values like justice and sustainability are strongly linked."

Eleonora Papadimitriou

"The justice of AI usage in transport safety is a key challenge to be addressed"



Riccardo Ferrari

Somewhat unexpectedly, Riccardo Ferrari's choice of a niche topic for his PhD, fault diagnosis, led to an exciting second life for his field of research. "You normally use fault diagnosis to monitor physical degradation and faults, but we extended it to deal with cyber threats. With one theory, we can now make systems like wind turbines or aeroplanes resilient to faults and secure industrial plants or autonomous vehicles against cyber attacks. Our next step? Teach an AI how devices, like electric car batteries, age. This is the kind of exciting cross-disciplinary research we want to do with colleagues at the Safety & Security Institute."

Following a PhD in Information Engineering from the University of Trieste, Riccardo spent seven years in industrial R&D in the steelmaking sector. He specialised in instrumentation and automation solutions for process control, first as a researcher and then as executive manager. His career path is considered unusual due to the return to academics after a comfortable position in industry. How did he get there?

"My first choice for further education was architecture, but I dropped the idea when my mother told me that my drawing skills were not good enough! My decision to study engineering was an element of chance. I used to spend time at my father's car mechanic shop after school, watching him work. Maybe it sparked curiosity for engineering."

"When I went on to a Masters in Electronic Engineering at the University of Trieste, I did an industrial thesis about detecting defects inside a steel object. We figured out that if you apply tension to that object and pluck it, like when tuning a guitar string, its sound can reveal if it is faulty! So acoustics and musical intuition helped to solve the problem."

Riccardo's interest in acoustics did not stop there. Alongside his MSc, Riccardo also juggled a BA in Classical Piano. "Yes, well, I almost got kicked out of the Conservatory. I wasn't getting the grades because I was simultaneously working on my engineering thesis. Luckily, I pulled it off and graduated (Grade 109/110). It was hard, but I believed it wasn't impossible. My (perhaps naive) view was that I could get a result if I put in the energy and effort. I also had the opportunity to write another thesis on acoustics! This time I added an engineering sparkle to a musical problem and built a computer model to analyse the influence of a pianist's touch on the sound you get out of the instrument."

When the same company that supported his Master's thesis offered Riccardo a PhD followed by an engineer position, it was an easy and logical choice. "I transitioned from academic to corporate life smoothly. But as the amount of research declined so did my interest. It was the path with the least resistance. In retrospect, I wonder whether it was the best path."

"During that period, I was still into research but had to write scientific papers during my free time. This double life became untenable when our first daughter was born, for good reasons! I re-evaluated my motivations and decided to quit my comfortable job and start a research position at Delft. All based on a one-year postdoc contract. Some might call it madness. But again, I believed that effort, energy and a bit of good luck would get me there."

Riccardo Ferrari is an Associate Professor in Fault Tolerant Control at the Delft Center for Systems and Control, within the Faculty of Mechanical, Maritime, and Materials Engineering (3mE) at TU Delft. Riccardo investigates how to make dynamical systems resilient against faults, malicious cyber-attacks and degradation phenomena whilst simultaneously fighting uncertainty.

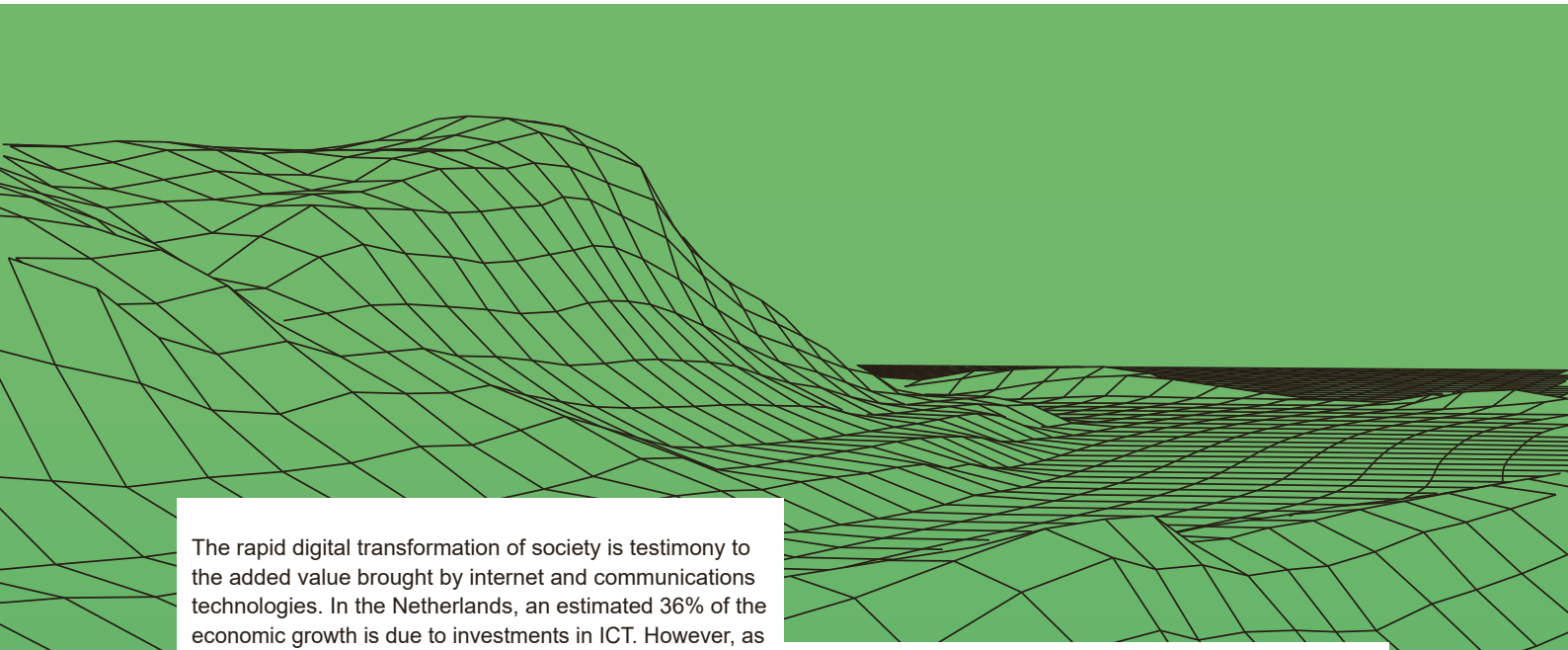
text Helen Hartmann **illustration** De Zagerij ontwerpbureau

text Ilse Oosterlaken **photo** Mark Voorendt

Beautiful and safe?

It is a common sight in the densely populated country of the Netherlands, houses along, on or even partly in a dyke. The result is picturesque scenes, which are an incredible sight if you cycle any of the 17,000 km of water-retaining dykes that protect the country. But those houses become obstacles when the dykes must be raised to cope with climate change-induced rising water levels. Therefore, Mark Voorendt and colleagues collaborate with other knowledge institutes and stakeholders to develop innovative alternatives. One example is Delta21, a citizens' initiative and integrated plan for a flood defence system in the form of a row of dunes, a pumping station and a closable barrier. The plan not only offers a solution for water safety, but also energy storage and nature restoration. This type of complex project is central to the minor Integrated Infrastructure Design that started a few years ago. Engineers of the future learn an integral approach to design and do research by design to keep the Netherlands both beautiful and safe in the coming decades.

Towards system resilience in an interconnected world



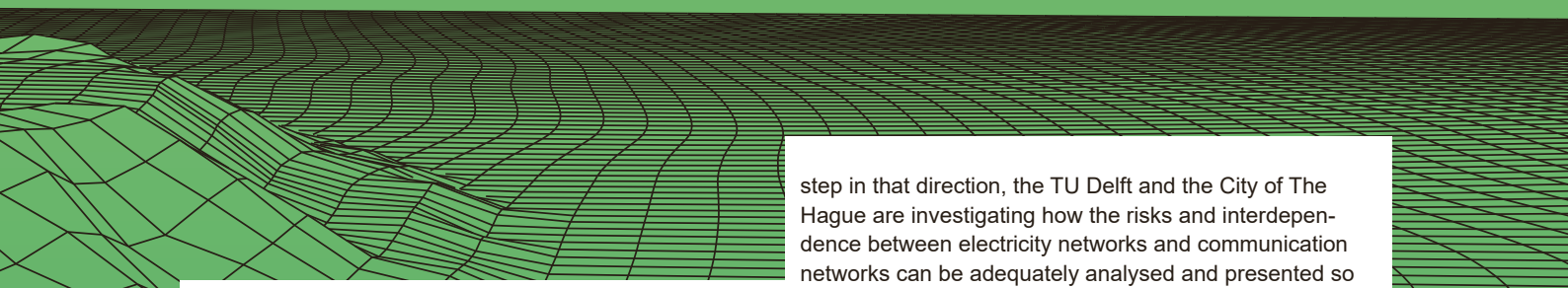
The rapid digital transformation of society is testimony to the added value brought by internet and communications technologies. In the Netherlands, an estimated 36% of the economic growth is due to investments in ICT. However, as people and ICT systems increasingly interconnect, dependencies are also introduced, posing risks to the security and availability of those systems. We have seen a multitude of cybersecurity incidents with significant societal impact already hit the news, ranging from ransomware to denial-of-service attacks inflicted by malicious entities. Digital infrastructures can also be affected by outages through other factors, such as human error due to increased complexity in operating networks, natural disasters, ageing of hardware, excessive traffic workloads, power disruptions, and so on. Moreover, many actors are typically involved in using or managing digital infrastructure, ranging from service providers to customer groups, multinationals, government agencies, NGOs, and critical infrastructure providers. The challenge is operating such complex multi-stakeholder systems and making them resilient. Systems thinking is required: the science, design, and engineering of complex systems. Such systems thinking should focus on functional properties, such as what the system should do, and non-functional properties that relate to how we would like those systems to work, in line with our norms and values: the human dimension!

From a cybersecurity perspective, system resilience is a critical concept. One could argue that the terms ‘cybersecurity’ and ‘system resilience’ are fundamentally linked: the level at which a system, an infrastructure or an organisation is ‘cybersecure’ is defined by its resilience: the degree to which it can withstand attacks, the time it takes to recover main functions, and the aptitude to learn and adapt to new circumstances. These abilities stem from an intricate interplay of technological, organisational, human, and infrastructural elements and typically cannot be acquired through simple product purchases or the adoption of universal standards. Cybersecurity emerges from a wide range of instruments and processes, such as vulnerability assessment, secure product design, cyber-skill development, monitoring and reaction facilities, robust recovery strategies, and failure forensics: aspects that nicely align with the current research themes of the TU Delft Safety & Security institute. Such instruments and processes are relevant for the resilience of any system, whether we are looking at a singular digital system, a specific infrastructure, or an entire business sector.

To safeguard current systems and futureproof the systems of tomorrow, we need to take significant steps forward in our understanding of ‘cyber system resilience.’ New European regulations, such as the Critical Entities Resilience (CER) Act and the Network & Information Security (NIS) 2 Directive, also call for cyber resilience and prescribe all kinds of related measures, but more is needed to establish system resilience. What makes a system more or less cybersecure, and what must we change to create a more resilient system? While these questions may seem abstract, they are more relevant now than ever. The rapid development of AI technologies, new digital infrastructures such as 6G, and the inevitable arrival of quantum computers will fundamentally change the threat landscape over the next decade. Our digital landscape will morph into a ‘digital continuum’ of (largely

When it comes to social security, there is broad consensus in the Netherlands that policy and implementation should focus more on the human dimension instead of the 'system's realit'. And for good reasons. Yet, Fernando Kuipers, Martijn Neef, and Daan Rijnders argue that cybersecurity requires more systems thinking to achieve resilience and respect the human dimension.

text Fernando Kuipers, Martijn Neef and Daan Rijnders



decentralised) compute, storage, and communications resources, with new capabilities and opportunities and potentially new vulnerabilities. Malicious actors will also use these new technologies to craft new lines of attack and test our system resilience to extremes.

Cyber resilience is about safeguarding digital systems against threats known and unknown, and in the understanding that current cybersecurity technologies and approaches (a) will not be enough to withstand the attacks of the future and (b) have to be made more cost-effective from a long-term perspective. Therefore, Cyber system resilience deserves the attention of research and innovation parties with the ambition to jointly create the groundwork for future digital infrastructures. Within that ambition, there are many outstanding challenges to be solved. For example, we need techniques to measure cyber resilience, new design paradigms that put cybersecurity at the heart of systems, new monitoring, recovery and mitigation strategies that can cope with unknown threats, etc. Every sector will benefit from such system-centered approaches; everywhere with IT/OT-based infrastructures and a complex interplay between humans and systems. In logistics, at sea, healthcare, energy, and any other domain where deep transitions occur.

Realising system resilience is clearly complex and, hence, best tackled jointly and interdisciplinary. As stipulated in the Dutch Cybersecurity Strategy, innovation policy already paves the way forward: we need to invest in cybersecurity technology, skills and processes to ensure the autonomy, resilience and robustness of our vital systems. As a first step in that direction, the TU Delft and the City of The Hague are investigating how the risks and interdependence between electricity networks and communication networks can be adequately analysed and presented so that practitioners can better assess and manage risk. This will help to develop better crisis response strategies and take more effective preventive measures.

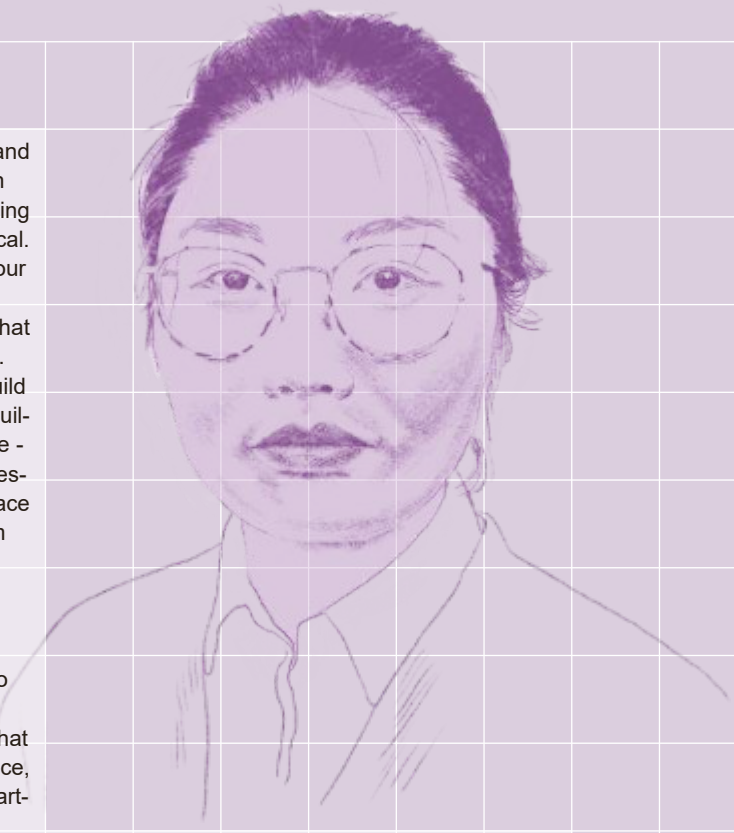
Joining forces nationally to take a (global) leadership role in the shaping of cyber-secure and resilient systems will not only dwindle the costs associated with the current omnipresent cyber security attacks, but it will also position the Netherlands as a secure, resilient, and hence trusted location for data and communications services.

Fernando Kuipers established and leads the Networked Systems group at TU Delft, where he works on Internet and communications technologies. He co-founded the PowerWeb Institute, is a member of the Board of the TU Delft Safety & Security Institute, and is the founding scientific director of the Do IoT fieldlab.

Martijn Neef is the Knowledge and Innovation Cybersecurity Coordinator at the Directorate of Digital Economy of the Dutch Ministry of Economic Affairs and Climate Policy.

Daan Rijnders leads the Cyber Secure The Hague program for the City of The Hague, which focuses on The Hague's unique risk profile as an International City of Peace & Justice and the cyber resilience of the local critical infrastructure & processes.

Nan Yue



"In high school, I loved physics. It was logical and easy to follow and came naturally to me. When choosing my bachelor's study, I wanted something related to physics and building something physical. When a group of university professors visited our region in China to inform students, I was lucky enough to meet some of them in person, and that meeting with them made an impression on me. In civil and mechanical engineering, we can build bridges, buildings, cars and ships. But we are building heavy, safe machines that fly in aerospace - it's complex and fascinating! The university professors were so proud of their field, calling aerospace 'the diamond of engineering'. Their enthusiasm was contagious, and I was smitten."

After her post-doctorate at Imperial College London, it was time to look for a new research topic with a different direction, which led Nan to TU Delft to research aircraft safety and how to ensure aircraft are fit to fly. "Until I discovered that Delft had an entire faculty dedicated to aerospace, I had only encountered it as a part of other departments or faculties. I was curious to investigate further, and Delft was at the forefront of my field." Previously, Nan spent five to six years working on a method to find damage in aircrafts. "Near the end of my post-doc, I knew I could detect the damage, but how could I translate the information into a practical decision-making process for it to be meaningful? I never thought my research was useless, but I knew it needed more. The truth is the more you research, inevitably you will find another hill to climb. In fact, I was happy, because it meant I was growing as a scientist."

"I learned about the Delft Technology Fellowship (DTF) on the university website at the end of my first year at TU Delft as a post-doc researcher. I asked myself if I could be happy in my future career without research. The answer was an emphatic 'No!', so it was an easy decision to apply. At the same time, I was certain that TU Delft would be a perfect place to start my academic career. I had already really enjoyed the one-year experience at the Faculty of Aerospace Engineering and felt inspired by the dedication to sustainable aviation.

My research vision evolved from realising that Structural Health Monitoring research needed a broader scope which considered engineering structures from cradle to grave." Nan's decision to pursue the DTF was confirmed during the preparation for the application. "I approached the professors at the ASM department to discuss my research vision and ask for advice, and everyone was very welcoming and supportive. When I was offered the DTF, I felt like the luckiest and the happiest person on earth."

"Looking back to when I first became smitten with aerospace engineering, and considering where I am now, I can say the feeling is only getting stronger. As I spend more time with aerospace engineering, I realise how complicated and sophisticated it is, and I'm still learning a lot every single day. When I teach students, it is always exciting to show how systematic and sophisticated a task it is to keep aviation as safe as it is today and to envision the future of sustainable aviation. I hope I radiate the same enthusiasm for aerospace engineering to my students as those professors did for me back then." It's fair to say that Nan's dedication to her field of research has matured into a full-blown love affair.

Nan Yue is an assistant professor in Structural Health Monitoring. She dedicates her research to bridging the knowledge and information gaps in design, manufacturing, in-service degradation and life management of lightweight, high-performance structures, using continuous health information gathered by integrated intelligent systems. She obtained her PhD in February 2020 and worked as a Research Associate at Imperial College London. She joined TU Delft as a Postdoc researcher in December 2020. In June 2022, she was awarded the Delft Technology Fellowship and became an assistant professor at the Department of Aerospace Structures and Materials.

text Helen Hartmann **illustration** De Zagerij ontwerpbureau

TU Delft Safety & Security Institute helps ideas grow

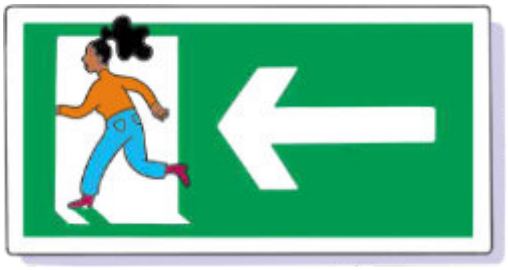
With its seed funding programme, TU Delft Safety & Security Institute aims to increase the joint impact of safety & security research and education at TU Delft. Through a yearly call for proposals, researchers are invited to send in a one-page idea for a project or activity. The idea behind 'seeding' is that a small incentivisation (up to 15,000 euros) can make a difference. Ideas must work towards 'a next step', something bigger to be achieved with people from different disciplines, and have societal relevance. Collaboration with non-academic stakeholders is encouraged. Since the start of the programme, 32 projects have been awarded. Six leading researchers present their funded projects here.

illustrations Menah

Safety & security aspects of evacuations

Natalie van de Wal

Faculties of AE, CEG, EEMCS and TPM*



Studying and learning from evacuations is of great importance to reduce casualties and risks in the unfortunate event of people having to leave a location urgently due to an emergency. Our novel approach combines state-of-the-art computer modelling with social and cognitive psychology insights on decision-making during evacuations. The aim was to design standard metrics for all campus buildings to record evacuations and drills. Evacuation drills at TU Delft were studied, as well as the protocols in place. What do people do when they hear the fire alarm? What are the routes they take? How can we record drills most effectively to learn from them and to share our best practices? A thorough understanding of the effectiveness of evacuations is needed to make TU Delft and any other place safe in times of danger. We hope to contribute to disseminating best practices and ensure that drills are designed and executed consistently and effectively. Researchers and practitioners must agree on standard metrics and data structures and establish a common data-sharing platform, ensuring that confidentiality, ethical requirements, regional contexts, and commercial sensitivities are observed.

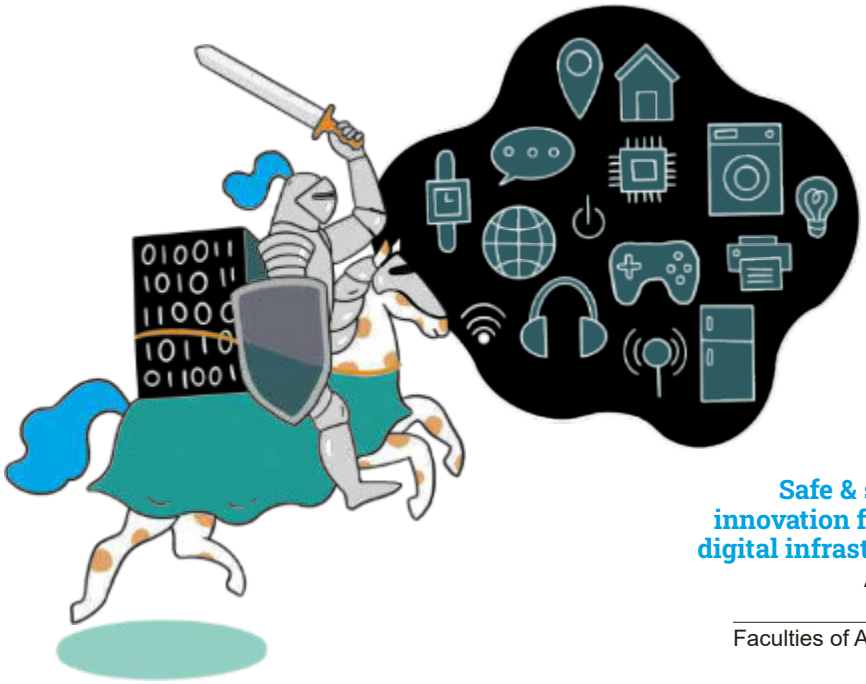
Process safety & security in the digital age

Ming Yang

Faculties of AE, AS, CEG, TPM and 3ME*

Digital technologies have been reshaping how process industries operate for more than two decades. This evolution has led to marvellous process automation and emerging risks and challenges. With a collaborative effort of several faculties and financial support from the TU Delft Safety & Security Institute, a virtual symposium was organised with more than 250 online participants worldwide. The participating researchers and practitioners reached a consensus that attention must be given to understanding the interactions of cyber-physical systems by adopting systemic thinking and from a multi-disciplinary perspective. This project also initiated a proposal for a book titled 'Methods to Assess and Manage Process Safety in Digitalized Process Systems'. The book, which was recently published, features leading international authors presenting state-of-art progress of digitalisation and corresponding opportunities and threats in process safety. Process resilience is suggested as a novel concept to support digitalised process system design and operation with emerging uncertainties and enhance a system's ability to handle uncertain disruptions.

*TU Delft Faculties A+BE = Faculty of Architecture and the Built Environment CEG = Civil Engineering and Geosciences EEMCS = Faculty Electrical Engineering, Mathematics and Computer Science IDE = Faculty of Industrial Design Engineering AE = Faculty of Aerospace Engineering TPM = Faculty of Technology, Policy and Management AS = Faculty of Applied Sciences 3ME = Faculty of Mechanical, Maritime and Materials Engineering



Safe & secure innovation for future digital infrastructures

Aaron Ding

Faculties of AE, EEMCS and TPM*

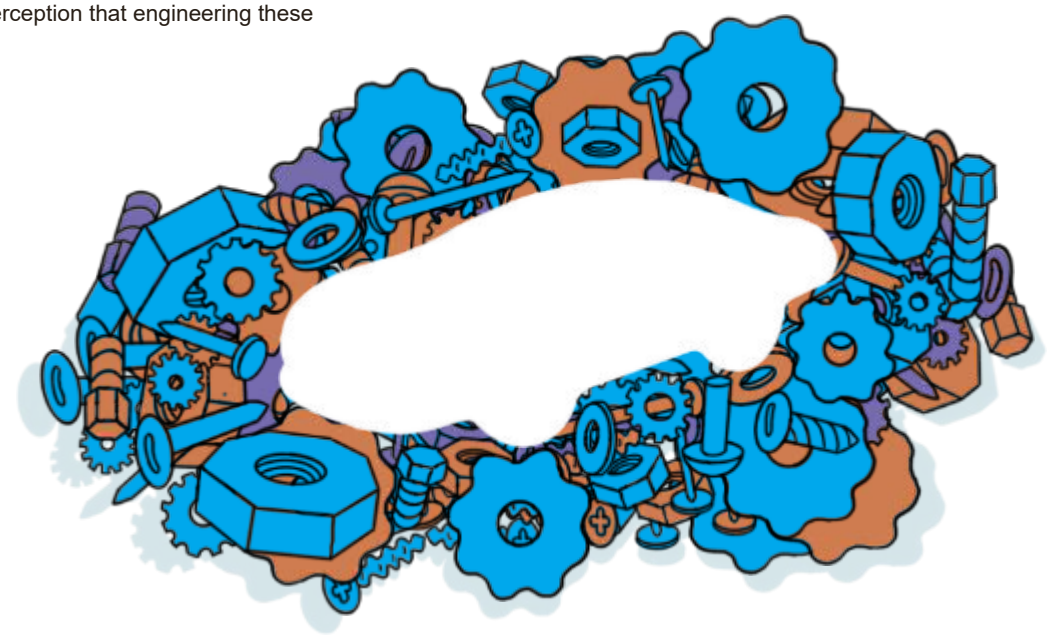
The fast-growing use of the Internet of Things (IoT) poses increasing and often unknown risks for the safety & security of digital infrastructures. We worked on building a living lab to jointly investigate IoT safety & security, especially the hardware-software vulnerabilities of IoT. With the seed funding of TU Delft Safety & Security Institute, we built a research consortium funded by the EU through the H2020 SPATIAL project, aiming to build the pathway toward a trustworthy European cybersecurity sector. TU Delft is in a leading position for safeguarding safe and secure innovation in these new IoT and Edge computing technologies.

Trespalacios - overengineering and safety: like oil and water?

Oscar Oviedo

Faculties of IDE and TPM*

Overengineering involves elaborately designing a product or problem-solving solution, even when a simpler and equally efficient alternative exists. We assert that overengineering also introduces safety risks. For instance, consider the case of a U.S. doctor who tragically perished in a post-crash fire because he couldn't exit the vehicle; Tesla's retractable door handles lack a manual opening option during malfunctions. The door handle issues persisted, with drivers struggling to enter their vehicles during winter due to icy blockages. Consequently, the practice of using "sticks on door handles" to remedy this problem gained popularity, unfortunately also increasing the carbon footprint. Despite the perception that engineering these handles was misguided, proponents argue that such inaccessible handles heighten security against external threats. This example accentuates the importance of considering overengineering and highlights the significance of integrating safety-related values comprehensively. We generate novel insights through case studies and workshops and inform research and innovation communities. By assembling experts, we envisage cultivating a deeper comprehension of the intricate interplay between overengineering, safety, and security. This endeavour, in turn, will bolster the campaign for advocating more conscientious engineering practices.



Predictive maintenance as a game changer

Marcia Baptista

Faculties of A+BE, AE, CEG, TPM*

Safety is a top priority for the aviation industry. Predictive maintenance is a novel approach to maintenance, deeply rooted in the techniques from Prognostics and Health Management (PHM). This approach aims to predict the state of an engineering system ahead of time. This can be a game changer in the prevention of aviation accidents, but also the enhancement of comfort and sustainability. For example, an aircraft's poorly maintained air conditioning system may not critically comprise safety, but it will surely negatively influence the comfort of passengers. Poorly maintained equipment, such as the aircraft engine or the landing gear, can also lead to sustainability issues and more pollution and waste (e.g. fuel). To give another example, unmanned aerial vehicles can pose a serious safety risk when their battery state is not managed correctly. A sudden battery discharge can lead to a safety collision or a mission abortion. Prediction with PHM can play a significant role here. It helps to reduce waste and safety risks.

We organised a series of seminars with top speakers in the field. The results are threefold: enhancing education and awareness, knowledge development, and establishing a strong network that connects research with industry, with partners such as KLM and Netherlands Aerospace Centre (NLR).

Connecting climate, economy, and water models

Jazmin Zatarain Salazar

Faculties of EEMCS and TPM*

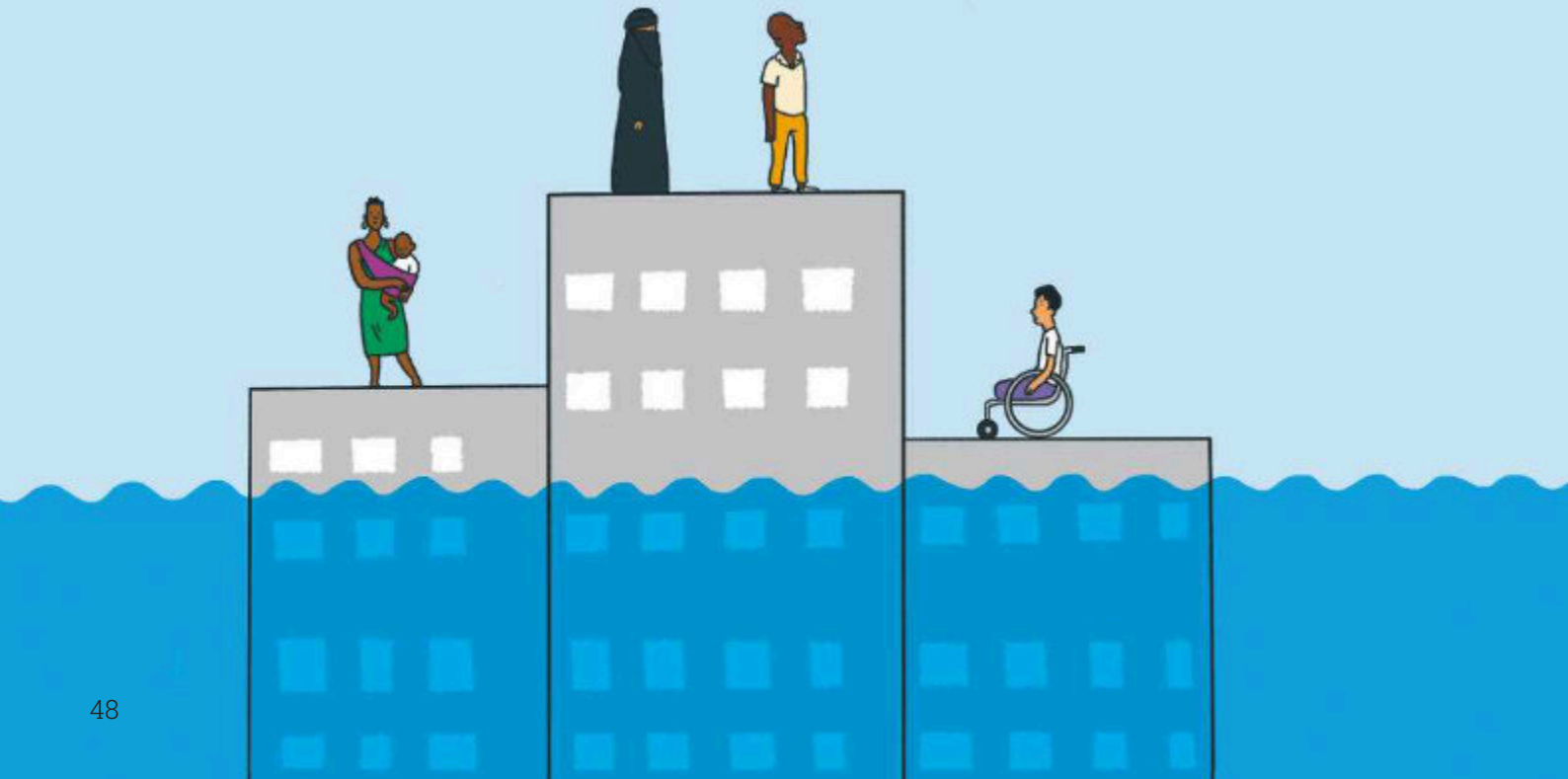
Climate policy and negotiations are being informed by global integrated assessment models (IAMs) that link economic and climate processes into a single framework. These models, however, fail to capture the distribution of risks at regional scales and rely on rough aggregations of the total cost of climate change. To this effect, we have developed methods that allow us to understand the benefits and risks at a regional scale for different mitigation trajectories. Further, we have developed and improved existing test cases, with a particular emphasis on West and Sub-Saharan Africa. These cases now serve as templates for modelling other systems. Our team has studied climate scenarios and adaptation policies to assess droughts and floods. Our open-source models enable us to explore scenarios and policies in water systems, and this was achieved by integrating programming support for code optimisation and fast, high-performance computing. Decision support is enhanced by innovative visualisation techniques. As a result, we have identified robust and stable policies that can withstand climate extremes. We believe these tools can provide essential guidance to develop socially acceptable policies for food security, energy needs, environmental considerations, and security of supply. This is especially important in large transboundary water systems prone to geopolitical tensions.

*TU Delft Faculties A+BE = Faculty of Architecture and the Built Environment CEG = Civil Engineering and Geosciences EEMCS = Faculty Electrical Engineering, Mathematics and Computer Science IDE = Faculty of Industrial Design Engineering AE = Faculty of Aerospace Engineering TPM = Faculty of Technology, Policy and Management AS = Faculty of Applied Sciences 3ME = Faculty of Mechanical, Maritime and Materials Engineering

A changing climate increases the magnitude and occurrence of natural hazards, such as floods. The conventional engineering approach to flood risk assessment is not good enough to address the societal challenges that natural hazards raise. Mariëlle Feenstra, Laura Stancanelli, and Elisa Ragno argue that more holistic approaches are needed, based on the values of well-being, equity, and inclusion.

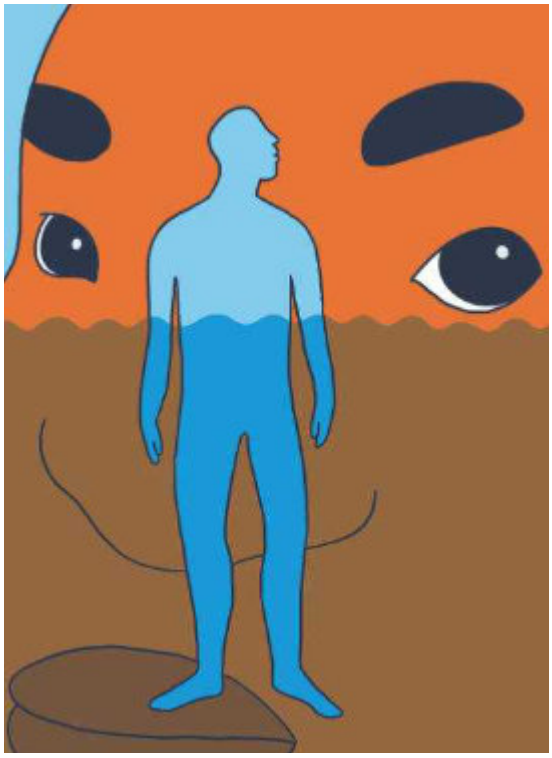
text Mariëlle Feenstra, Laura Stancanelli and Elisa Ragno **illustrations** Menah

We need an inclusive approach to flood risks



The conventional engineering approach to flood risk assessment focuses on event magnitude – considering flood peak, flood wave speed, and inundation area - and the associated estimated economic and physical damages to infrastructures and individuals. In this approach, the physical impact of floods on human beings is usually estimated by adopting a biased, universalised prototype of the human body and calculating its stability under flood waves. There are several reasons for us to claim that a more holistic, value-based approach is needed.

Firstly, in addition to physical damage and economic losses, natural disasters also take an emotional and psychological toll on individuals and communities. Trauma, anxiety, and depression are common emotional responses with long-lasting effects on mental health and well-being. The emotional and cognitive aspects of disaster impact should be considered when assessing risks and designing response strategies.



Secondly, natural disasters do not affect all human beings equally; Their impact is not solely determined by forces of nature but also by varying degrees of exposure and unequal access to opportunities. Low-income neighbourhoods, for example, may lack the necessary infrastructure and financial means to withstand floods or evacuate when necessary. Additionally, marginalised and vulnerable communities often have limited access to early warning systems and disaster preparedness education. These communities are not only disproportionately affected by natural hazards, but these hazards may also further increase existing social inequalities.

Diversity of human beings

Within communities and societies, many differences between human beings determine the impact that natural hazards have on them. Gender is one such factor. Women represent the majority of the world's poor population and, particularly in the Global South, often lack access to education, food, clean water, and health services. As a result, they are more vulnerable to extreme weather events, such as floods and droughts. Climate-induced migration, driven by extreme weather and rising sea levels, further exposes women to vulnerability, Gender-Based Violence (GBV), and poverty. Women often have limited access to and control of environmental resources, and energy poverty disproportionately affects women, hindering their ability to participate in climate change adaptation measures.

A gender lens thus reveals alarming insights into the drivers and dynamics of a changing climate since the climate crisis enlarges existing gender inequality, forcing women and girls to bear the brunt of its effects. This underlines the need to explore more holistic, inclusive, and value-based perspectives for flood risk reduction and emergency response.

Although gender is an important factor in the diversity of human beings, it is not the only one that matters. People differ in many ways, and we should consider a range of characteristics, conditions, experiences, perceptions and responses. People may, for example, have varying perceptions of risk, influenced by factors like cultural background, past experiences, and trust in authorities. They may also have different understandings of the prevailing environmental conditions and the vulnerability of buildings and other structures. The ability to respond to and cope with climate change also depends on physical characteristics and cognitive capacities. Caregivers may have different concerns and possibilities to react to events and crises than non-caregivers.

Inclusive technological solutions to flood risks

In summary, the unequal impact of natural disasters, aggravated by a changing climate, highlights the need for comprehensive and inclusive approaches to disaster preparedness and climate action. This requires re-evaluating risk assessment methods and broader societal efforts to reduce gender inequality, address unequal access to resources, and promote resilience in vulnerable communities. Education is a key factor in increasing climate resilience, as it equips individuals with the knowledge and skills to address natural disasters and the impacts of a changing climate.

In this context, a multidisciplinary team of researchers from three TU Delft faculties - Civil Engineering & Geoscience (CTiG), Architecture & the Built Environment (A+BE), and Technology, Policy & Management (TPM) – have joined forces in the 'InSync' seed project, funded by the TU Delft Safety & Security Institute. This project aims to shift from an engineering-centred approach to a transdisciplinary approach to flood risk, with the ultimate aim of developing inclusive technological solutions to flood risk that take into account existing inequalities and human diversity. InSync is currently building an international network of academics to collaborate and develop a partner consortium for European-funded research and innovation projects on this topic. We welcome discussion and collaboration!

Mariëlle Feenstra is a senior researcher on gender just energy policy and an experienced policy advisor.

Laura Stancanelli is an assistant professor in the River Engineering group of the Department of Hydraulic Engineering.

Elisa Ragno is an assistant professor in the group of Hydraulic Structures and Flood Risk in the Department of Hydraulic Engineering.

In the world of biotechnology, safety and sustainability might sometimes be at odds. When conflicts arise, decision-makers must carefully weigh the trade-offs, addressing potential risks and ethical concerns in order to make informed choices. According to two TU Delft professors, safety and sustainability need to go hand in hand to ensure that biotechnological processes and products are developed and managed responsibly.

text Heather Montague

Lotte Asveld and Ulf Hanefeld discuss:

Are sustainability and safety incompatible?

Risks and responsibilities

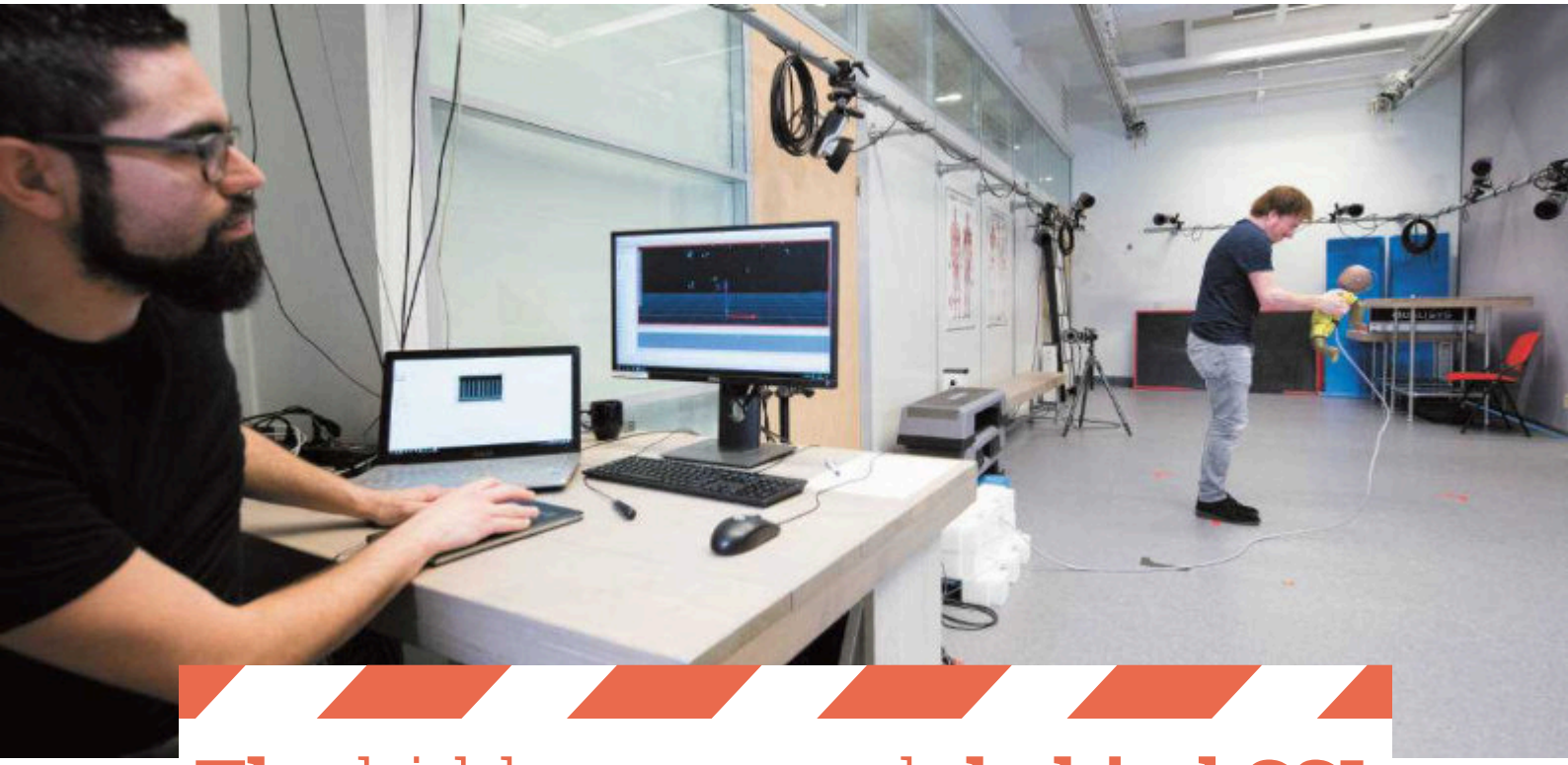
With the rise of the circular economy, finding ways to use waste for other purposes has become a hot topic. But there are risks involved, says Lotte Asveld, Associate Professor of Ethics & Biotechnology at TU Delft. “People have high standards when it comes to using wastes as resources. Anything that comes out of the sewer doesn’t feel very comfortable to have in your house.” In that sense, she sees a clash between sustainability and safety but also believes they should be combined. “We can’t make everything 100% safe, but we should look towards what risks people find acceptable.” Societal acceptance of using waste as a resource requires that regulations and responsibilities be well aligned.

We also need to reevaluate the way we learn about risks, according to Asveld. She notes that biotechnology is strictly regulated, but in the chemical industry, companies themselves are responsible for learning about and identifying risks. “As new risky substances keep emerging, what needs to happen in the innovation ecosystem to make sure that these responsibilities have a place?” Learning about these risks is not always an inherent part of a company’s structure and that needs to change. “My objective is to make sure that safety is something that we talk about, that we don’t take for granted, that we discuss amongst each other; what does it mean, how can we achieve it, and how do we see our responsibility to society and achieving safety?”

The future is green

The term ‘green chemistry’ was introduced some thirty years ago, according to Ulf Hanefeld, Professor of Biotechnology at TU Delft’s Faculty of Applied Sciences. The aim is to enable society to make what is currently made, or alternatives, in a sustainable and safe manner. “So how can I make the compounds that we as a society think we need in a sustainable manner, starting from readily available materials, performing reactions that are inherently safe,” says Hanefeld. “For me, safety and sustainability go hand in hand.”

There are advantages and opportunities that come along with green chemistry. If you take all the starting materials, make only products out of it and don’t generate any waste, that results in higher profit. And there is also an opportunity to develop a new chemistry. “Consider that our current chemistry always starts from petrochemicals, which are very low in terms of functionality,” Hanefeld explains. “If you use sustainable materials like sugars or lignin or plant waste, that is always highly functionalised. Because we have a new type of starter material, we’re doing it all new, and it is a chance to develop it safe from the start.”



The hidden research behind CSI

In TV series like CSI: Crime Scene Investigation, it seems almost effortless to analyse a crime scene and draw conclusions; Just put the lab equipment to work. However, it takes a lot of effort to develop the technologies and methods that real-life investigators use and ensure they are reliable. This is the work area of Arjo Loeve, who leads the research line 'Forensic Biomechanical Engineering' in the field 'engineering for forensics' at TU Delft.

Can you give some examples of work at TU Delft in forensics?
"One project that I am particularly proud of is the FreeRef system that we developed and validated in collaboration with the Dutch police and the Netherlands Forensic Institute (NFI). This system improves forensic photography during evidence gathering. Current practice is to hold a ruler as a size reference next to a footprint or trace of blood while taking the photo. Our intelligent system can record measurements without using rulers, with higher accuracy, more work freedom and without the risk of disturbing evidence. This tool could really lift forensic investigations to a new level.

Another good example is our research on inflicted head injury by shaking trauma in infants, often wrongfully referred to as the 'shaken baby syndrome'. Over the past few years, we have revealed several flaws in current investigation methods. It's problematic, as innocent parents may unrightfully lose custody of their children, or children may wrongfully be kept under the custody of abusive parents. We are now working on better approaches to investigate cases like these. Soon, we will ensure that court rulings on this matter become more evidence-based and reliable."

What challenges and opportunities do recent technological and societal developments provide for forensics engineering?
"Due to the recent developments in AI and data science and our increasingly digitised society, the focus on funding, research, and media tends to be digital forensics. But it's a simple truth that not all crimes or incidents are filmed or logged in any way and that many essential traces and evidence are not digital and never will be. So, it's crucial to keep at least a significant part of funding and research focused on the more physical aspects of the forensic field. Luckily, police and forensic investigators also realise that, so I don't worry too much, but it's a constant point of attention."

Is there something like a 'TU Delft approach' of engineering for forensics?
"I like to think so. At TU Delft, we are good at dissecting design problems to their core. I come from the biomedical field, in which clinicians often approach us with a problem already stated as a solution. For instance, I have problem A, so I need you to develop solution B… but often the perceived problem A is only a symptom of underlying problem C, needing solution D. Revealing C and coming up with an as simple as possible D is something we do very well in Delft. This might be even more important in the forensic field than the clinical one. Users are even more reluctant to change their habits because if what they had was good enough, there's a serious risk in changing that."

Arjo Loeve is assistant professor at the Department of Biomechanical Engineering of the TU Delft Faculty of Mechanical, Maritime and Materials Engineering.

Self-adapting trailblazers

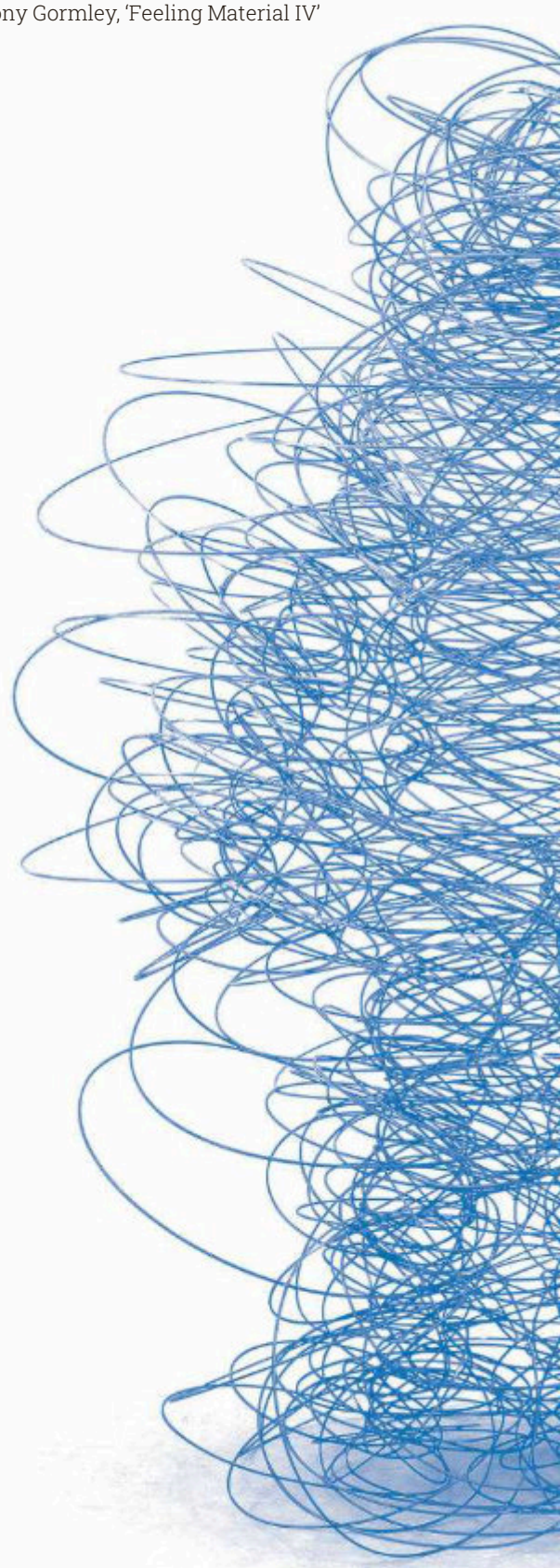
This smoothly moving orange object is probably not what most people imagine a robot to look like, yet that is what it is – a smart underwater robot. Or, in more official terms, it is an Autonomous Underwater Vehicle (AUV) or unmanned maritime system. These systems can be used for a range of safety & security-related operations, such as checking and protecting pipelines lying on the seabed (like the Nord Stream gas pipeline), underwater surveillance in ports, cleaning up sea mines, and anti-submarine warfare. They have the potential to take over lengthy and labour-intensive missions from navy ship crews and divers, which would be especially welcome in dangerous areas. Crucial to their success is a seamless integration in the wireless and diverse network of surface ships, submarines, and sensor nodes. However, timely disclosure of the 'big data' collected underwater (e.g. sonar tracks and photos) to operators above water via a surface gateway is difficult, as the wave motion of the sea surface creates a delay/Doppler-spread effect. TU Delft (Richard Hendriks), NLDA (Richard Heusdens) and TNO are collaborating to solve such challenges.

text Eveline Vreede & researchers **photo** TNO

The theme 'Safety & security in a changing world' ran through this magazine like a common thread, although sometimes only implicitly. To conclude, we reflect on this theme with Genserik Reniers, Professor of Safety of Hazardous Materials and head of the Safety & Security Science section at TU Delft, who effortlessly delivers a mini-lecture and shares his thoughts.

text Ilse Oosterlaken **interview** Eveline Vreede and Ilse Oosterlaken **sculpture** Antony Gormley, 'Feeling Material IV'

Safety & security in a changing world



Safety & security…
'Safety' prevents harmful incidents due to natural disasters or human error. 'Security' is about incidents involving malicious intent, for example, by terrorists or criminals. 'Security' is often viewed more qualitatively (for example, from the perspective of psychology or political science), and 'safety' more quantitatively (for example, in economic or technical analyses).

It is therefore not surprising that in the Netherlands, 'security' has traditionally been a problem area that non-technical universities mainly address, and 'safety' has historically received more attention at TU Delft. Of course, there are exceptions, 'cyber security' also gets a lot of attention in Delft. But the fact that both his section and the TU Delft Safety & Security Institute so explicitly bring the two values together is nevertheless quite unique, says Reniers.

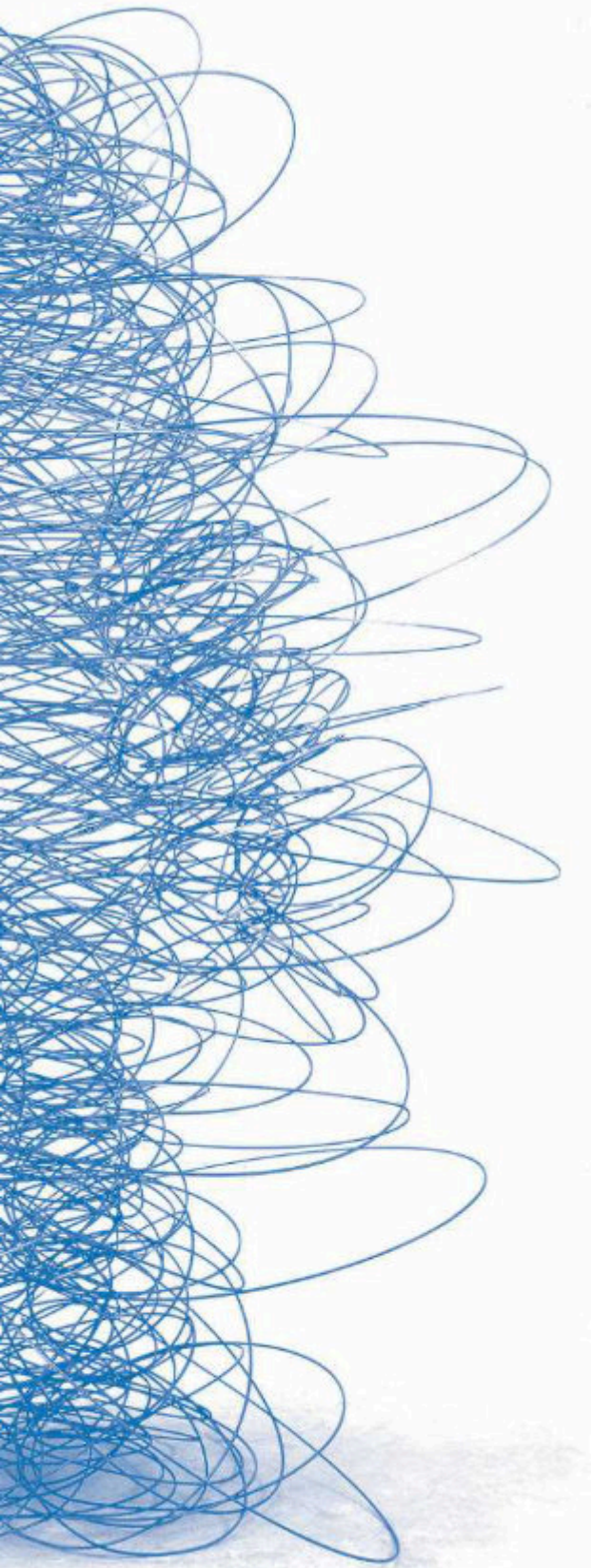
In most companies and organisations, they are not viewed in an integrated manner either. There is generally a separation in budgets, personnel and departments that deal with these two values or problem areas. This separation is the result of historical developments.

A barrier in bridging the gap is that – at least in the Netherlands – these values are the domain of different government departments; 'Safety' has traditionally been the responsibility of the Ministry of Infrastructure and Water Management, while 'security' is instead seen as belonging to the territory of the Ministry of Justice and Security. One consequence is that legislation surrounding these two challenges is not viewed in conjunction, and according to Reniers, this does not give companies and organisations any incentive to do so either. It really depends on local 'champions', the people who see the usefulness and benefits, whether that happens.

"It would be interesting to discuss this with more companies," says Reniers, "but I am happy that at least more and more people know the difference between the two." Language does not always help with this (see box).

…in a changing world
But what is the benefit and usefulness of an integrated approach? Here, we finally arrive at the theme of a changing world. The website of the TU Delft Safety & Security Institute gives several examples of why 'security' is becoming increasingly important for engineers: Cars are increasingly becoming "computers on wheels" and can be controlled remotely, which makes 'security' as much a challenge for developers as 'safety'. And "the well-developed structures of strong dykes may not be as safe as expected if the flood defence system becomes hackable." In short, physical 'safety' and 'cyber security' become increasingly intertwined as information technology

"With the world's growing complexity it is difficult, if not impossible, to predict what will happen. So we have to be prepared for a lot of options"



gets integrated into everything and cyber-physical systems become more common, Reniers confirms.

While creating this magazine, digital developments were not the only thing we discussed concerning a 'changing world'. We also considered, for example, climate change and the transition to a sustainable economy, the increasing public attention for (in)equality and inclusion, and recent geopolitical developments. Can Reniers also say something about that? "Those are quite big themes!" is his first reaction. Of course, according to Reniers, there is a lot to say about each of these developments, but where do you start? Concerning climate change, for example, it is interesting, he believes, that natural disasters used to be mainly something that the government dealt with. But nowadays, companies in the EU are also obliged to make risk analyses on so-called 'Natech' risks. And while in the past, the emphasis in the field was mainly on preventing natural disasters, it is now more about 'self-reliance', or how we can deal with it if something like this happens.

In fact, Reniers reflects further on the magazine theme, the same developments in the field of safety & security science are important for many of these significant societal developments. For example, increasing attention is being paid to the dynamic nature of risk analyses because risk levels constantly change over time.

With increasingly interconnected sectors and systems, it has also become more important to consider possible incidents in a larger context, more systemically. Small events that do not pose a problem for the security of a system on their own can, if occurring simultaneously, potentially have a major impact on it. In the last 5 to 10 years, various new analysis methods have been developed that include the systemic aspect of safety, such as FRAM (Functional Resonance Analysis Method) and STPA (Systems Theoretic Process Analysis). Research on such methods is still quite academic, and they are rarely applied in practice. So there is still much to do in the coming years in collaboration with stakeholders.

Finally, with the world's growing complexity, we increasingly realise that risks are difficult to assess. That is why 'resilience' has become such an important topic in recent years. It is difficult, if not impossible, to predict what will happen. So we have to be prepared for a lot of options. "If you are resilient," Reniers concludes, "you can handle many safety & security challenges."

'Safety' and 'security' in different languages

The clear distinction that is made in English between 'safety' and 'security' is not present in all languages. In Dutch, the word 'veiligheid' is in practice used for both, which can cause confusion. Strictly speaking, there is another Dutch word that could serve as a specific translation of 'security', namely 'beveiliging', but in practice it is not common to use it in that way. The word mainly evokes associations with the personal protection of people who have received threats. In French there are two words, 'securité' and 'sûreté'. But surprisingly enough, the first is the translation of 'safety' and the second of 'security'. A Frenchman and an Englishman could therefore easily misunderstand each other if they do not have a good command of each other's language.

Today's grand challenges can no longer be solved with a single perspective or approach

Aukje Hassoldt
Dean TU Delft Faculty of Technology, Policy and Management