

EEMCS Towards 2020

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1 Dean's preface



In 2016 we celebrated the 110th anniversary of Electrical Engineering in Delft, and at the same time we opened the Tellegen Hall for EE project education. These events call for some historical background to this midterm update of the EEMCS multi-annual plan 2012-2020.

At the end of the 19th century, Jan Snijders, head of the physics practical lab at Delft Polytechnic, was a strong advocate of founding an electrical engineering department, as he realized the huge potential of the novel electrical phenomena for innovation. With the assistance of his friend Heike Kamerlingh Onnes he established the EE department in 1906. Soon afterwards, Clarence Feldmann, a young professor from Darmstadt, came to Delft. Feldmann and his fellow EE professors played a crucial role in creating the electricity infrastructure in the Netherlands. The electronics interests of Kamerlingh Onnes inspired physicist Gilles Holst to create Philips Research and to hire Bernard Tellegen (Delft EE degree in 1923). Together, they worked on radio tubes and in 1926 this resulted in the invention of the Pentode. Tellegen, first professor and later honorary doctor at TH Delft, is the only Dutch winner of the Edison Medal, the Nobel prize for EE.

WWII, Tellegen pushed hard in Delft for investments in (analogue) electronic calculating machines. This was eventually picked up by a young physicist, Willem van der Poel. Van der Poel created one of the first computers in the Netherlands on the basis of a variety of specializations in Delft. His creation, the Testudo, was later followed at PTT by Ptera and Zebra. These innovations inspired an essential set of research activities in Computer Science, then centered in the Applied Mathematics department.

So the founding fathers of EEMCS had a profound influence on our society by combining deep scientific insight, oftentimes coming from various disciplines, with innovation opportunities.

Moving forward, it is unlikely that such radical transformations of society will be restricted to scientifically based technological innovations. Many EEMCS-oriented embryonic innovations are on the steep rising side of the Gartner curve. In most of them, societal aspects play a vital role, and socio-technical approaches are essential. At EEMCS we connect with "smart" as in smart phone, smart industry and smart city; we connect with "digital" as in digital society and digitization of education. These innovation trends are often cross-disciplinary, and we are regularly concerned that our staff members are becoming the "invisible helpers" of publicly rewarded "scientific celebrities".

Inspired by our successful predecessors, our strategy needs to be based on deepening our mono-disciplinary understanding on the one hand, while developing multi-disciplinary themes on the other. We have therefore chosen to articulate these two strategic views: the disciplinary strategies of our departments as well as the cross-faculty themes.

This approach has led to several new areas of education and research, such as Delft Data Science for data analytics, bio-medical research in bio-informatics, bio-electronics and organ-on-chip, cybersecurity and quantum engineering. In addition, we have put a spotlight on already existing areas, such as the transition into renewable electricity, computational science and engineering, and sensing & communication.

The faculty has seen a very significant increase in its bachelor and master students, and non-EEMCS students have joined our courses in great numbers as well. This is indicative of the assumed future relevance of our fields of study. The appreciation of our education and our staff's involvement have increased nicely. We are very proud of the many awards won by our teaching staff. However, the redefinition of our research focus and the investment in educational innovation are done by approximately the same number of scientific staff as at the start of this multi-annual plan period. We experience a higher than acceptable workload for our scientific and support staff, and the rate of burn-out cases is increasing. We will need to balance our ambitions in education and research more carefully against the size of our staff.

Rob Fastenau
October 2016

2 Management summary

This update of the multi-annual plan of the Faculty of Electrical Engineering, Mathematics and Computer Science - entitled "EEMCS towards 2020" - is based upon the existing multi-annual plan 2012-2020. Now, halfway through that original planning period, the predicted digital society is becoming a reality. At the same time, electrical engineering, mathematics and computer science have been recognized as the "innovator of the innovators" in many scientific and societal domains. This is also reflected by the increased popularity of the EEMCS education programmes.

Opportunities in research, education and valorization are abundantly present, and sometimes even overwhelmingly alluring. These developments call for a vision on EEMCS's future that is both sustainable and flexible. Sustainable enough to provide a reliable basis for all primary processes in research and education while, at the same time, flexible enough to embrace new and high-risk opportunities. This is why the current plan follows through on a number of the EEMCS "themes" in addition to an approach in terms of department strategies. The themes represent major collaborative efforts within EEMCS in relation to innovation opportunities, major societal challenges, and enablers for educational and organizational development. Depending on developments and opportunities in the outside world, the existing themes may disappear, or new themes can be added. Plus a section on EEMCS values has been added to the multi-annual plan. We believe that embracing these values is a critical success factor for realizing EEMCS's ambitions.

Updated EEMCS Strategic Priorities for 2017-2020

- Ensure continuity of EEMCS's research and education activities during the entire process of relocating the faculty.
- Enhance efficiency and effectiveness in accommodating the increasing number of bachelor students, a smoother inbound/outbound transition to HBO, and accommodating (international) student populations with heterogeneous backgrounds.
- Update curricula from the perspective of relevance, profile, and EEMCS thematic focus with a continued focus on quality, and the introduction of data-driven analysis to measure the effects of educational innovation.
- Use MOOCs and online courses as part of campus education and to help international students to prepare for their studies at EEMCS.
- Expand the EEMCS themes, increase national and European impact, and reach out to (internationally) highly ranked knowledge partners with a similar thematic focus.
- Create impact and visibility through publications and individual grants on the one hand, and collaborative project grants and technology transfer on the other.
- Exercise influence on national and European programming (H2020, cPPP big data, cybersecurity, energy transition), understand project acquisition success and fail factors, improve technology transfer, entrepreneurship, and entrepreneurial education.
- Act fast and make an impact when opportunities emerge.
- Emphasize EEMCS values and the agility of the EEMCS faculty as a means for transparent management.



3 EEMCS in a broader context

Digital transformation of society and science

The digital transformation - spurred ahead by mathematics, electrical engineering, and computer science and technology - has become pervasively present in our society. Digitization greatly influences how we live, connect, work and learn; how we deal with our health and wellbeing; how we secure our society against physical or cyber threats; and how we provide for clean and efficient energy production and consumption in the future. We are just at the beginning, and we can expect further acceleration of the digital transformation process.

All transformations take place in the international arena. A digital service developed on the other side of the globe may disrupt the Dutch economy, society or science. At the same time, a service developed in the Netherlands has the potential to become world-famous. Due to the disruptive and dislocated nature of digitization, there will be few winners and many losers. EEMCS aims for a role among the leaders in digital transformation in areas of typical Dutch strengths such as energy transition, health, infrastructure, and safety and security. A range of reports on digital transformation has been published by advisory bodies and branch organizations over the past few years. All of them confirm its importance. Information and Communication Technology (ICT) is characterized as extremely impactful and “the innovator of innovators” in all sectors of society, economy and science. A large percentage of organizations is actively implementing a digital transformation strategy. Such strategies range from the use of internet-of-things technologies to advanced sensors, from mathematical modeling to computational simulations, and from value creation using data science to value protection using cybersecurity.

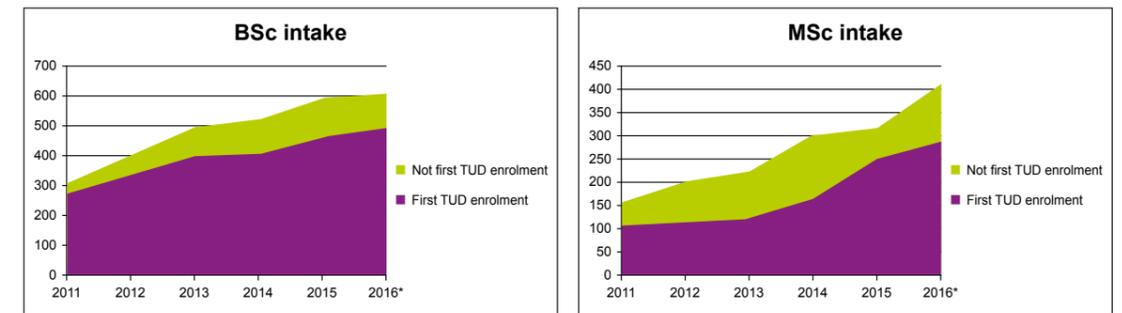
The software industry in the Netherlands comprises 44,000 companies. The Dutch high-tech industry has several major international businesses such as ASML, Philips, NXP, and VDL. And the Netherlands has many established firms in the software-driven financial sector. The ICT sector is responsible for 5.1% of GDP, and over 30% of the economic growth. At the same time, these reports unanimously sound alarm bells about the lack of ICT talent in the Netherlands, and the disproportionately small capacity in ICT education and research relative to the needs and growth of the ICT sector.

Digitization is also becoming one of the crucial players in a rapidly changing electrical energy sector. In addition to new technologies for electricity generation from renewable energy sources such as solar and wind energy, electronics components, storage and sensors, it will become the basis for the future intelligent power networks. Electrical power engineering with its multi-disciplinary character has become a focus of interest for the power industry since the energy transition towards sustainable energy will take place mainly in the power sector.

TU Delft and the Faculty of EEMCS are extremely well-positioned to bolster talent-breeding and research-based innovation that serves people and society. This requires strategic choices, however, that enhance research and education in electrical engineering, mathematics and computer science.

Increased popularity of education programmes

Over the past few years the pervasiveness of digital science, technology, products and services, and their role as change agents have also had an effect on the number of students in electrical engineering, mathematics and computer science. At a national level, in five years' time the number of bachelor students starting each year in electrical engineering roughly doubled from 250 to 500, in mathematics this number tripled from 300 to 900, and in computer science it tripled from 600 to 1800. At the Faculty of EEMCS, a similar growth is seen: electrical engineering from 100 to 200, mathematics from 50 to 200, and computer science from 100 to 300. A major increase can also be observed at the master level. In addition, the international contingent of students is growing.



BSc and MSc inflow: *2016 was measured in week 37, deviating from 1 December of the previous years.

While this growth strongly corroborates with the digital transformation, it is leading to a decrease in budget and time for research, which is worrying. The relatively large percentage of drop-outs and negative BSAs are stimulating even more faculty-intensive education efforts. The ICT Research Platform Netherlands (IPN) and the Platform Wiskunde Nederland (PWN) both launched a call to action, and the latter has already led to funding of parts of the Wiskunde DeltaPlan. The popularity of ICT education is also highly noticeable in emerging economies in China, India and Africa. Many leading universities have actively developed a presence in the form of international collaborations, foreign campuses, or online education. Such strategic choices cater to teaching more foreign students and, at the same time, strategically position these universities in the international competition for student and faculty talent with other highly ranked universities and attractive companies such as Facebook, Google, Apple, IBM, Microsoft and Samsung.

Challenges to research funding

Electrical engineering, mathematics and computer sciences are broad fields in which unexpected developments may potentially occur in any subarea. For instance, the recent surge in research and application interest in the topics “blockchain”, “FAIR data access”, and “quantum engineering and software” could hardly have been foreseen a few years back. Yet they are on the current agenda of many researchers and practitioners in electrical engineering, mathematics and computer science. For that reason, fundamental and unbound research is important, and funding through individual grant schemes such as NWO Veni-Vidi-Vici, ERC, and NWO open competitions is essential. Unfortunately, the overall funding percentage has been steadily dropping over the years, currently leading to an alarmingly low number of projects being funded (NWO has a funding percentage of less than 15%, and for H2020, the number of funded research proposals has dropped below 5%). This exerts great pressure on faculty members to submit as many projects as possible.

The potential scientific or economic value of some ICT research areas has led to establishing larger scale collaborations and collaborative programmes. Examples of EEMCS domains in which regional and national collaborations have emerged include data science, complexity, cybersecurity, disease model technologies, and the four mathematics clusters (DIAMANT, NDNS+, STAR and GQT). The National Research Agenda (NWA) recently published the EEMCS-related research routes “Big Data”, “Smart Liveable Cities”, “Energy Transition”, “Smart Industry”, “Personalized Medicine”, “Measure and Detect”, and “Quantum/Nano Revolution”. In 2015, the ICT top team developed the strategy for public-private collaboration in ICT across top sectors, known as the Knowledge and Innovation Agenda ICT. This agenda emphasizes topics such as “complexity”, “cybersecurity”, and “big data”. The HTSM top team defined similar ICT-related agendas for the domains of “smart industry” and “high-tech to feed the world”. Most of these topics have major international and Horizon2020 counterparts. Regionally, HSD and Medical Delta are important for EEMCS, and nationally 4TU.NIRICT emphasizes building faculty communities and new leadership. TU Delft and the Faculty of EEMCS have been actively taking part in shaping all of the above-mentioned agendas and will continue to do so in the coming years, following the strategic choices outlined in this multi-annual plan.



4 EEMCS departments

Department of Intelligent Systems (INSY)

One pervasive trend is to quantify more and more aspects of the world and our lives through data. Datafication is radically influencing the way people, companies, societies, and governments exist and operate. This creates new opportunities as well as new hazards. The INSY department aims to enable man and machine to deal with the increasing volume and complexity of data, in close cooperation with their environment. Together with the software technology department, INSY is responsible for the Computer Science bachelor programme and the two master tracks, Software Technology (ST) and Data Science & Technology (DST). The department also contributes to the Computer Science specializations Cybersecurity, Bioinformatics, and EIT Innovation of the master in Digital Media Technology.

The department integrates fundamental research, engineering and design in the interlocking fields of data processing, interpretation, visualization and interaction using model- and knowledge-based methods and algorithms. The research is inspired by challenges from the domains of consumer electronics and entertainment, cultural heritage, social media, medical and health sciences, security and privacy, and safety and incident management. The department underpins the EEMCS thematic research lines Data Science, Safety & Security, and Health & Wellbeing.

Strategic priorities:

- Attract more externally funded, part-time academic staff from knowledge organizations (such as TNO and CWI) and industry.
- Increase international visibility scouting abilities through strategic collaborations, personnel exchange and visitors' programme.
- Strengthen the cybersecurity section to meet the rapidly growing educational demands and the pervasive presence of security in the EEMCS thematic lines.
- Improve our technology transfer by initiating a budget for software/tool development serving different sections and research objectives, and for scientific programmers.
- Strengthen the education capacity in view of the rapidly rising popularity and impact of computer science education, both in the field of intelligent systems (AI, machine learning, pattern recognition) and across the university as a whole.

Department of Software Technology (ST)

The Department of Software Technology addresses fundamental questions in computer science from a systems and experimental perspective. It uses its strong basis in core disciplines such as distributed systems, software engineering, embedded systems, programming languages, data science, and algorithms to establish innovations in domains such as smart grids and cities, finance, gaming, and e-learning. In education, the department has been successful in launching a number of very popular online courses (MOOCs in functional programming, data analysis, and introductory programming). Given the growing demand for computer and data scientists and the increasing popularity of the bachelor and master courses in computer science, the department will further innovate its educational programmes through a balanced mix of on-campus and online learning. Given its strong involvement in the Delft Data Science initiative, the department intends to broaden its data engineering expertise, its connections to industry, and its overall societal impact.

Strategic priorities:

- Scale up and continue to innovate educational programmes by blending on-campus and online learning.
- Establish strategic collaborations with industry in areas that are in high demand, such as internet-of-things, blockchain, continuous deployment, software modeling, and data science.
- Demonstrate research excellence through personal grants and high-profile international collaboration in fundamental areas such as programming languages, distributed systems, and algorithms.
- Safeguard a healthy balance between teaching and research activities for the department's staff, despite high student enrolments.
- Offer a stimulating and engaging work environment in order to attract the best new staff in the highly competitive computer science market.

Highlight

Dr Przemysław Pawelczak, Assistant Professor with the Embedded Software research group, is involved in the wireless revolution: the combination of wireless energy and communications. The technology that Przemysław Pawelczak is studying centres on the backscatter principle. The device used is not a source of energy itself, but instead harvests the energy from another device that sends and receives data. Information is sent by - to put it simply - rapidly turning the energy 'on and off' using a transistor. Pawelczak's current research is directly entwined with the future network of the internet-of-things (devices that all carry tiny chips and communicate with each other). If you insert a tiny chip or tag in an object or a living thing, you preferably do not want to have to remove it again. So he prefers to use devices that need no energy themselves and that can be reprogrammed remotely. The chips in these devices will theoretically have eternal life. His research project on a reprogrammable chip, called WISP, that harvests its energy from ambient radiofrequency radiation, was published in the spring of 2016.

A wisent is a European bison, a little reference to Pawelczak's Polish roots, but it is also an acronym for Wirelessly Sent.

Department of Applied Mathematics (DIAM)

Mathematics has become a key enabling technology for innovations shaping our modern society. With a clear focus on furthering our understanding of complex systems in science, society and technology, DIAM covers a broad spectrum of research: from fundamental work aimed at understanding systems at a deep structural level (e.g. Operator Theory) to the development of tailor-made mathematical models and tools that can be used in a variety of domains (e.g. mathematical modeling of wound healing). The department has a leading role in the theme Computational Science & Engineering. Besides educating its own students, the department takes care of all mathematics teaching in other programmes at EEMCS and at other faculties (service teaching). Recently, two popular MOOCs, Pre-University Calculus and Credit Risk Management, were developed. The department's aim is to sustain and strengthen its position as a highly qualified research and educational institution.

Strategic priorities:

- Achieve a balance between research and teaching activities by increasing DIAM's research capacity (permanent staff) in the coming years (tenure-track and full professor positions).
- Continue education innovation projects to improve quality and efficiency.
- Enhance DIAM's position in service teaching in various engineering master programmes.
- Strengthen ties to strongly mathematics-related themes within the university (e.g. QuTech, Health & Wellbeing, Delft Data Science); both in terms of research and education.
- Maintain DIAM's leading position within Delft Institute of Computational Science and Engineering (DCSE).
- Explore possibilities for a mathematics helpdesk for TUD colleagues; broadening and professionalizing the current statistics helpdesk.
- Apply for European funding and personal grants (NWO) more strategically, in both engineering and fundamental mathematical themes.
- Consolidate and strengthen participation in mathematics clusters (DIAMANT, NDNS+, STAR and GQT).

Highlight

Geurt Jongbloed is Professor of Mathematical Statistics. His research group has been commissioned by KNMI to investigate how the likelihood of extreme weather can be calculated. KNMI (Royal Netherlands Meteorological Institute) wants to improve its short term predictions of extreme weather events. Such events have occurred several times in the past. Geurt Jongbloed's research group is looking for output variables in the existing weather models that actually provide an indication of - or show a relationship between - extreme weather conditions, but which have not been interpreted as such so far. This means that certain parameters may already exist in these models that, when they indicate certain values, could warn us when we need to be extra alert.

Essentially, the researchers are using all the various background variables to gain an understanding of extremes. This is a lot of data to analyse, and to make things even more complicated, they are also examining extremes with two variables. An example is the Maeslantkering (Maeslant Barrier) in Rotterdam. This barrier can be closed if heavy weather is approaching from the North Sea. However, if the rivers are discharging extreme amounts at the same time, then closing the barriers will cause half the country to be inundated. But what is the likelihood of this doomsday scenario actually happening?



Department of Microelectronics (ME)

Microelectronics is one of the main drivers behind the digital revolution that is transforming our world. In line with this, the research and educational activities of ME span all aspects of electronic engineering, ranging from electromagnetics and signal processing to hardware design, and from microfabrication to the realization of complete radar arrays. ME's research includes the design and development of silicon-based devices, analogue and digital circuits for smart sensors, biomedical implants and wireless communication systems, signal-processing algorithms for communication and biomedical signals, as well as microwave and terahertz systems for remote sensing and radio astronomy. The department is responsible for the BSc programme in Electrical Engineering, as well as for three tracks in the MSc Electrical Engineering programme: Microelectronics (ME), Signals and Systems (SS), and Telecommunications & Sensing Systems (TS). The department is also a major contributor to the EEMCS themes: Next Generation Sensing & Communication, Safety & Security, and Health & Wellbeing.

Strategic priorities:

- Recruit highly talented senior staff, as well as externally funded, part-time academic staff from key industrial partners.
- Intensify research in rapidly growing areas, such as biomedical systems, automotive radar, cognitive sensing, terahertz sensing, CryoCMOS, 5G wireless systems, and electronics for the internet-of-things.
- Maintain strong links with the new Quantum Engineering department.
- Enhance and facilitate vertical integration by combining the results of multidisciplinary research within the department into complete demonstrators.
- Pursue the ample opportunities for direct funding from industry.
- Ensure the availability of sustainable, future-proof research infrastructure, e.g. the Cryolab, the radar lab, and the EKL cleanrooms.
- Participate in the national educational benchmark for BSc Electrical Engineering, and invest in teaching support for projects and practicals.

Highlight

Dr Akira Endo, who works for Tera-Hertz Sensing, is developing a completely new measuring instrument with which astronomers will be able to study the most active galaxies much more effectively.

The new spectrometer, called DESHIMA, will hopefully provide us with new knowledge on the birth of stars and galaxies. The goal of the research is to create 3D charts of so-called submillimetre galaxies that, in contrast to 2D charts, also show distance and time. Submillimetre galaxies are the most active star systems, and we have difficulty studying them using traditional telescopes because they produce a large amount of dust. The research is focusing on the period from when the universe was a sixth of the way through its existence up until approximately half-way. This was the time at which the star systems and their stars were at their most active. The developments in such systems can be investigated by studying protons and terahertz waves. In early 2017, they hope to test the spectrometer in the telescope for which it is intended: the ASTE telescope in Chile.

Department of Electrical Sustainable Energy (ESE)

The ESE department's research activities aim at accelerating the energy transition towards sustainable energy. The research covers electrical energy generation from renewable energy sources, its transmission, distribution and storage. The department designs and fabricates high-performance, low-cost photovoltaic (PV) cells and power electronics devices for integration in future power networks. It studies systems with electricity generation using PV and wind technologies, high-voltage and direct-current transmission, and intelligent power management for increasing energy efficiency. In anticipation of the large-scale introduction of renewable and distributed energy sources, the technical, economic and societal performances of the future electricity system are studied through multidisciplinary "system of systems" approaches. Working on this energy transition, the ESE department contributes to tackling important societal challenges such as climate change and environmental pollution. The department plays a leading role in the EEMCS thematic line Energy Transition.

Strategic priorities:

- Establish the new Electrical Sustainable Power (ESP) lab.
- Strengthen the department's strategy of multidisciplinary cooperation in developing future electrical energy systems.
- Invest in resolving the current imbalance in age composition of research teams, for instance by appointing a number of part-time professors in cooperation with national companies.
- Maintain a leading position in the Powerweb programme.
- Redesign and strengthen the MSc programme SET.
- Participate in the national educational benchmark for BSc Electrical Engineering, and invest in teaching support for projects and practicals.

Department of Quantum Engineering (QE)

Quantum Computing and Quantum Internet are seen as possible game changers in information technology, enabling a new category of applications which are currently not feasible on conventional computing platforms. There are various application domains that could benefit from this new technology, such as quantum chemistry, where new molecules are synthesized, which could lead to new materials or personalized medical treatments. Quantum Internet could provide virtually unbreakable communication mechanisms and thus create the basis for a truly secure Internet. The QE department is focusing on the engineering challenges involved in scaling up these quantum technologies so they can be used for real-world problems. In this respect, QE performs research on quantum system architecture, CryoCMOS, 3D interconnects, and quantum information theory. The QE department is closely connected to the QuTech research labs. The entire scope of research activities, going beyond quantum, is related to several other EEMCS themes such as: Computational Science & Engineering where QE contributes to the future computing topic with its memristor-based computing and reliable computing using unreliable device research, Data Science where QE contributes primarily to the health and computational genomics topics with the big data architectures research line, and Safety & Security where QE focuses on hardware-based security mechanisms and fully adaptive processor architectures.

Strategic priorities:

- Build a strong QE department that encompasses both quantum and non-quantum activities.
- Continue the close collaboration with QuTech, in both research and teaching, for example in the context of QuTech Academy.
- Increase entrepreneurial activities by establishing at least two spin-off companies.
- In addition to the relationship with QuTech, continue to leverage and expand research and education relationships with departments within EEMCS.

EEMCS themes towards 2020



INNOVATION OPPORTUNITIES

Quantum Computing

Description of theme

The Quantum Computing theme is directly coupled to the QuTech mission of building a quantum computer and a quantum Internet. It involves formulating and building the system and device concepts necessary to scale the current quantum-related technology to a level where it can be usefully applied.

Scientific challenges

- Perform research on quantum architecture, CryoCMOS, interconnect, repeaters, network protocols and quantum information theory in the context of building the quantum computer and the quantum Internet.

Educational challenges

- Develop new courses for the QuTech Academy.
- Make an edX MOOC on quantum computing.

Societal & industrial challenges

- Deliver quantum technologies for secure communications and safety.

Ambitions for the coming years

- Contribute to the EU Quantum Flagship project.
- Realize the Intel project deliverables and milestones.
- Develop 2 to 3 courses on quantum computing-related topics.
- Leverage the NWA route “the Quantum/Nano Revolution”.

Computational Science & Engineering

Description of theme

Computational Science & Engineering (CSE) deals with the development and application of computational models and simulations, often coupled with high-performance computing, to solve complex physical problems arising in engineering analysis and design (computational engineering), as well as natural phenomena (computational science). In many fields, computer simulation is integral and therefore essential to business and research. Computer simulation provides the capability to enter fields that are either inaccessible to traditional experimentation or where carrying out traditional empirical inquiries is prohibitively expensive. Together with KTH and TU Berlin, a joint master programme is offered (COSSE), originally funded as an ERASMUS MUNDUS project.

Scientific challenges

- Develop accurate and effective algorithms for application fields in large-scale (future) computing.
- Enable future computing by exploratory research on and development of algorithms and systems based on these new concepts.
- Develop acceptance criteria for, and objective confidence measures in, information obtained from models and simulations. The aim is to decrease uncertainty about nature and physics problems.
- Make a significant contribution to High Performance Computing (HPC) and open source software.

Educational challenges

- Develop scientific programming courses for bachelor and master students.
- Develop Computational Fluid (CFD), Advanced discretization methods and High Performance Develop Computational (HPC) courses for PhDs and professionals.
- Design a minor programme and a master track.
- Organize joint Summer Schools with Shanghai Jiaotong University (SJTU) for potential cooperation between both universities.
- Continue COSSE programme now Erasmus Mundus funding has stopped.

Societal & industrial challenges

- Reduce design & simulation times and prevent animal testing by optimizing computational models.
- Provide a platform for academicians and industry to:
 - Develop new interdisciplinary computational models for sustainable developments.
 - Enhance computational tools for engineering applications.

Ambitions for the coming years

- Take the leading role in developing problem-solving techniques and methodologies utilizing computational techniques and simulations to accurately model natural phenomena.
- Become an authoritative community on computational science and engineering-related research, education and technology transfer for both peers and industry at the university, at a national and international level.
- Expand collaborations with other Delft Institutes, such as DUWIND, Delft Climate Institute, Robotics Institute and Delft Data Science (DDS).
- Strengthen collaborations with industry, for instance with Shell, MARIN, Deltares, NLR and ASML.
- Strengthen long-term partnership with government and non-governmental organisations, e.g. NWO.
- Join forces with national and international universities and computational science-oriented institutes.

Data Science

Description of theme

Within EEMCS, the data science theme is closely connected to the DDS programme (Delft Data Science). It covers the challenges of turning big data into knowledge and insight. Big data is everywhere and considered one of the world's biggest IT-related societal challenges. The rapid expansion of the web and the explosive evolution of software and hardware technology have resulted in immense amounts of digital data. This digital data comes with properties, e.g. size, speed, and semantics, that pose unprecedented challenges. Smart processing and intelligent analyses are required to obtain useful insights from big data, which may lead to value and impact in both science and society. Almost every field of study or sector of society will be fundamentally changed through (or will be affected by) big data. Naturally, the data science theme is closely connected to all EEMCS themes and covers a wide range of application domains, such as smart cities, health, security, online education, and sports.

Scientific challenges

- Reduce the gap between the available computer power and the complexity of big data.
- Improve the reliability and performance of big data analysis.
- Enhance cognitive computing for real-time automatic decision making.
- Advance social data analytics through expanding social data computing.

Educational challenges

- Set up bachelor-level 'service' education in data science (to make the basics of data science generally accessible to all TU Delft students).
- Start professional education and master classes in data science.
- Expand education in data science in computer science and mathematics bachelor courses.

Societal & industrial challenges

- Develop new models for the experimentation and valorization of big data technology within real-world domains.
- Increase sustained collaboration with scientific stakeholders in domains that use big data to advance science (AMS, HSD, MD, SEI).
- Develop new models for industrial collaboration with providers of big data and data science technology.

Ambitions for the coming years

- Develop a new world-class expert group in 'Engineering for Data Science' within EEMCS.
- Advance the expertise in large-scale data visualisation and visual analytics in health-related sectors.
- Establish a leadership position in all focus domains for 'Social Data Science'.
- Start a data science minor, expand bachelor-level data science education and master classes in data science for professionals.
- Realize the SAnDS lab for 'Social Data Science'.
- Realize a Delft Data Science (DDS) helpdesk for TU Delft colleagues.
- Continue the shaping of the NWA routes "Big Data", "Sport", and "Smart liveable cities" and the top sector programme "Commit2Data".

Next Generation Sensing & Communication

Description of theme

The human desire to live in "smart environments" and "to be connected anywhere, anytime" is changing the way we interact with our surroundings and will drastically impact our society. As a result, wireless data traffic is growing exponentially and is driving mobile networks and their devices from 4G to 5G services, to handle more users and services at higher data rates and lower latency. In contrast, the Internet-of-Things requires the connectivity of large numbers of devices at low data rates, but with very strict requirements on response times and energy usage. For environmental monitoring and autonomous transportation, microwave and THz sensing systems are expected to play a crucial role. Accurate wireless localization will also be essential. The Next Generation Sensing & Communication theme aims to pioneer the next generation of wireless communication and sensing systems with enhanced functionality and a low ecological footprint. The required disciplines are analog, digital and RF circuit design, antenna design, electromagnetic wave propagation and scattering, signal and data processing, networking and embedded systems. The theme is expected to make strong technological contributions to the TU Delft Space and Climate institutes.

Scientific challenges

- Design agile, energy-efficient wireless systems that can handle a wide range of data rates, ranging from low (few Hz) to extremely high (hundreds of GHz), as well as dynamically allocated frequency bands.
- Develop sparse antenna arrays for multiple beam operation and agile beam-forming techniques to reliably implement spatially distributed (massive) MIMO wireless systems.
- Develop distributed remote sensing systems for multi-functional, multi-user applications.
- Develop high-speed, but ultra-low power, signal processing and energy-efficient spectrum sensing.
- Design ultra-sensitive THz detectors for space-based research into the origins of the universe.

Educational challenges

- Introduce common core courses to enhance the synergy between the various MSc EE tracks and better address the broad scope of the Next Generation Sensing & Communication theme.
- Improve the connection of the MSc EE Telecommunication and Sensing track with the other MSc EE tracks, as well as with the MSc Embedded Systems.

Societal & industrial challenges

- Contribute to the definition of 5G standards.
- Contribute to autonomous driving by developing sensors (radar/camera/lidar), cognitive sensing algorithms and sensor fusion.
- Develop car-to-car communication and localization systems.
- Realize distributed, high-resolution, real-time weather-monitoring systems.
- Reduce the environmental footprint of communication systems.

Ambitions for the coming years

- Develop distributed radar systems and radar networks (Delft-Rotterdam-Cabauw).
- Implementation of intelligent sensors (radar/camera system) and localization systems for autonomous cars.
- Deploy a state-of-the-art THz array camera in a radio telescope.
- Deploy the first European sub-mm wave Airport Security System.
- Contribute to the NWA routes "Measure and Detect" and "Smart Industry".

MAJOR SOCIETAL CHALLENGES

Safety & Security

Description of theme

Safety and security is a cross-cutting theme not only for the Faculty of EEMCS, but for Delft University of Technology at large and - in fact - the whole of today's society. Our perspective on the theme is a technical one, focusing on physical (remote) sensing abilities for public and industrial safety and security on the one hand, and on awareness and appropriate measures in cyberspace on the other. Whereas initially the two perspectives on safety and security were fairly independent, the advance of cyber-physical systems and Internet-of-Things (IoT) increasingly interweaves the physical and the cyber-domain. In this theme, we seek collaboration with other technical and non-technical disciplines via national and international collaborations. Particular domains of interest for the Faculty of EEMCS are smart grids in the context of the energy transition, cognitive sensing in the context of environment monitoring and autonomous driving, and cyber safety & security in the healthcare domain, e.g. of biomedical implants.

Scientific challenges

- Since safety and security incidents will be impossible to avoid, creating situational awareness, both in physical and cyber spaces, is a central scientific challenge. We focus on the methodology and technology for gathering mission-specific data and the intelligent processing of the collected data into meaningful information for decision support.
- Safety and security measures may lead to the collection of private or competition-sensitive data in public spaces, communication networks, and government- or company-owned databases. Whereas the public and policy debate on what is acceptable continues, we research which and to what extent technology itself can provide answers to privacy and confidentiality concerns.
- To make systems and software safe and secure, we focus on theory and engineering methods in a range of disciplines - from software engineering to hardware design, and from system-of-systems engineering to data protection.

Educational challenges

- The Faculty of EEMCS initiated a 4TU Master-level cybersecurity specialization (as part of the Master programme in Computer Science) and co-developed a post-initial executive MSc programme in Cybersecurity within the Cybersecurity Academy in The Hague. Our challenge is to let these programmes mature in terms of content and programming. From a longer-term sustainability perspective, the programmes need to be embedded into the organization with broader support among faculty members.
- Safety and security are topics with which we aim to leverage the natural complementarity with the Faculty of TBM and LDE partners in educational programmes centered in The Hague.
- We aim to develop several MOOCs and/or other e-learning means in the field of safety and security engineering and technology, including post-academic education.

Societal & industrial challenges

- Make public and cyber space a secure environment for individuals, business and other organizations, government, and its stakeholders.
- Drastically improve transportation safety by realising driver assistance and autonomous driving systems.
- Improve public safety by developing high-resolution body scanners.
- Enlarge national and international public-private partnerships in all fields relevant to the scientific challenges, from software engineering to hardware design, and from system-of-systems engineering to data protection.
- Leverage our regional (HSD with many safety and security companies, government organizations) and international (Singapore, Japan) network to drive use-inspired research and to maximize the relevance of our scientific research results.

Ambitions for the coming years

- The topics of safety and security demand closer interaction between research groups within and outside the Faculty of EEMCS. The Delft Institute for Safety and Security (DSyS) is an appropriate means to catalyze this interaction.
- Although society demands an increasing number of specialists in safety and security technology, funding for PhD positions is not easily obtained from government or industry. We will need to increase the number of PhD students within EEMCS working on a safety and security topic.
- Substantially grow the EEMCS research community by hiring faculty with strengths in the domain of safety and security.
- Cybersecurity attracts students with highly heterogeneous backgrounds. EEMCS will need to find ways to deal with such a heterogeneous student population.
- Leverage the national cybersecurity platform DCYPHER and investigate possibilities for participation in NWA route “Between Conflict and Cooperation”.
- Participate in the NWA route “Small liveable cities” with high-resolution, real-time weather-monitoring systems and autonomous driving.
- Extend collaboration with Thales France on radar sensors for weather monitoring.

Energy Transition

Description of theme

The Energy Transition aims to transform the present energy system that is based on fossil fuels into one based on renewable energy sources. As such, it is one of the driving forces of the TU Delft DRI “Delft Energy Initiative”. In addition to the usual power electronics and electrical engineering challenges, information and communication technology challenges and solutions are increasingly entering the domain of the energy transition. The main challenge is to realize this transition at the lowest possible cost without compromising the system’s reliability. Since the most important renewable energy sources (solar and wind energy) deliver electricity, the primary challenge is to accommodate energy transition in the existing electrical power system. Consumers are increasingly becoming electricity producers by installing their own photovoltaic (PV) and wind energy systems. In this way, power micro-grids are formed where power management and market mechanisms can be controlled locally. By interconnecting the micro-grids, the stability and resilience of the entire electrical power system can be increased, and conversion and transport losses can be minimized. When consumers mutually exchange electricity or deliver electricity to the distribution network, new market design and regulations have to be developed and put into place.

Scientific challenges

- Expand our vision and research agenda for system integration of renewable energy sources, storage and sustainable loads.
- Perform research, design and development of PV building elements.
- Design and implement microgrids for smart cities, integration of electric vehicles (EV) with electricity from renewable energy, and components and control strategies for DC distribution grids.
- Improve the scalability and reliability of smart grid mechanisms, including new market mechanisms and the use of big data.
- Develop high-voltage DC superconducting cable and components and materials for offshore transmission.

Educational challenges

- Expand professional education on solar energy focused on PV.
- Strengthen the TU Delft-wide education in the technology of and transition to DC systems and smart grids.

Societal & industrial challenges

- Develop a high-voltage, meshed transmission network to allow integration of large-scale renewable energy sources.
- Enhance large-scale integration of renewable energy sources in the existing power network and the increasing number of electric vehicles.
- Decrease energy use and continuous improvement of energy efficiency, for instance through smart grids and the use of computer science methods and internet.
- Develop new business models for energy supply and demand.
- Increase collaboration with traditional industry (such as Tennet, Stedin, Eneco, etc.) on the topics of reliability and efficiency, and with IT industry on topics such as consumer energy savings, the use of data science methods, and privacy protection in smart grids.

Ambitions for the coming years

- Realize the new Electrical Sustainable Power (ESP) lab.
- Implement the new SET curriculum and obtain accreditation.
- Strengthen and expand the TU Delft PowerWeb programme in collaboration with the Faculties TBM and 3ME.
- Start the SolarUrban programme.
- Strengthen the connection to NWA (route “Energietransition”) and top sector Energy (TKI Urban Energy).



Health & Wellbeing

Description of theme

The health and wellbeing theme involves a wide diversity of researchers from the Faculty of EEMCS. Their involvement ranges from microelectronic devices for human organ and disease models to mathematical biophysics, and from implantable medical devices to genomic data analysis and visualization. The theme Health and Wellbeing is well embedded into the TU Delft DRI “Medical Delta”, and many regional (LDE) and national (NKI, VUMC, Hubrecht Institute, Dutch Burn Centre, LUMC, 4TU) collaborations exist. The aim is to contribute to faster and more accurate diagnostics, advanced therapy, improved health-related quality of life (also for healthy people, to improve productivity and overall societal participation), and better prevention, care and cure, at reduced cost. In microelectronics, the design and implementation of biomedical microsystems address challenges such as high-quality signal modeling, miniaturization, accuracy and reliability, energy efficiency, biocompatibility, manufacturability and cost. Research encompasses material and technology, device and circuit design, signal processing, system implementation and software design. In mathematics and computer science, models and algorithms are being designed that advance health cure and care. The central challenges are the analysis of massive volumes of health, treatment, and genomics data, including personal lifestyle data, medical imaging data, and a range of multi-modal molecular data as well as the (cyber)security and privacy aspects of health data.

Scientific challenges

- Extreme miniaturization, energy efficiency, flexibility and closed-loop control of implantable devices and ultrasound catheters and probes.
- Flexible and customized organ-on-a-chip platforms.
- Reverse-engineering the brain: brain signal processing (hardware emulation, i.e. computational neuroscience/bio-inspired circuits and algorithms), understanding molecular processes.
- Single-cell analysis: finding spatio-temporal patterns, capturing lineages and (tissue) heterogeneity.
- Data integration (across several modalities) and knowledge discovery.
- Mathematical modeling of biological phenomena.
- Mental health computing and behavior change support systems using virtual health agents.
- Cybersecurity and protection of privacy-sensitive information in biomedical devices, services and data.

Educational challenges

- Multidisciplinary/interfaculty programmes and new courses for students with heterogeneous backgrounds (e.g. Biomedical Engineering, Clinical Technology, Electrical Engineering, Medical Physics, Industrial Design).
- Contributing to the upcoming MSc Clinical Technology and BSc Biomedical Engineering, and expanding the MSc EE Signals & Systems track to include a biomedical signal-processing track.

Societal & industrial challenges

- Reduce costs and time of drug development.
- Optimize use of available resources, e.g. limited number of ambulances.
- Reduce hospital/care costs by minimally invasive medicine; living longer at home.
- Address ethical and privacy implications of medical technological innovations.
- Contribute to the HPTC research programmes.

Ambitions for the coming years

- Strengthen the internal coherence of the health and wellbeing thematic line.
- Develop expertise in biomedical signal-processing.
- Continue and expand regional collaboration, such as participation in Medical Delta.
- Expand collaborations with medical institutions such as EMC, LUMC, UMC, and VUMC, focusing on use of our technology and solutions (e.g. probes, data modeling and analysis, visualization) in clinical trials.
- Strengthen the involvement in the NWA route “Personalized Medicine”, as well as KNAW’s big infrastructure HEALTH-RI (NL Personalised Medicine & Health Research Infrastructure).

ENABLERS

Educational Innovation

Description of theme

The education portfolio of EEMCS consists of:

- 3 BSc programmes in Electrical Engineering, Applied Mathematics and Computer Science,
- 5 MSc programmes in Electrical Engineering, Computer Engineering, Applied Mathematics, Computer Science and Embedded Systems.
- The master programme Sustainable Energy Technology (a collaboration between faculties; EEMCS coordinates it as of September 2016)
- All mathematics courses in other bachelor and master programmes at TU Delft.
- A number of MOOCs and some ProfEd courses.
- Cooperation within 4TU (Embedded Systems & Cybersecurity), Erasmus Mundus programme and EIT Digital Master School.
- A small number of dual degrees with foreign universities.
- Other forms of education such as PhD training and contract education.

Students greatly appreciate the high-quality education offered at EEMCS, which is reflected in several award-winning lecturers (e.g. lecturer of the year of the Netherlands and lecturer of the year of the TU Delft) and MOOCs (e.g. Solar Energy and Pre-University Calculus). Over the past couple of years, the focus has been on the modernisation of on-campus maths courses, development of MOOCs and online courses, and updating the master programmes in Electrical Engineering and Computer Science.

Ambitions for the coming years

- Continue and extend the campus-wide modernisation of maths teaching for the next 3 to 4 years.
- Prepare the introduction of the full English-taught bachelor programmes in CS and EE (as of September 2017).
- Develop (in close collaboration with the Haagse Hogeschool) an outflux option to a university of applied sciences (HBO) for drop-outs, i.e. bachelor students that stop their enrolments before February 1st.
- Host the LDE CEL professorship and stimulate the Centre for Education and Learning (CEL) to be an effective change agent in on-campus and online education within the three partner universities.
- Implement, in collaboration with DCE (Delft Centre for Entrepreneurship), an “integrated” Annotation Entrepreneurship of 20 EC within the current master programmes CS and EE.
- Start a 4TU Centre for Engineering Education which addresses, as one of its main challenges, how teaching in the bachelor programmes of EE and CS can be made more efficient and more effective.
- Develop the student-engagement project “Faces in the crowd”.

State-of-the-art Research Facilities

Description of theme

EEMCS has three main labs in the low-rise building that are focused on EE research and education. Definitive plans exist to concentrate most of the research infrastructure of the ESE department in the Sustainable Power Lab in the current High-Voltage building. The Else Kooi Lab (EKL) is one of the two major cleanrooms (connected) of the TU Delft. EKL supports micro-electronics, micro-systems, organ-on-chip, photovoltaics and cryo-measurement. In the Tellegen hall, EE project education is concentrated together with power electronics, electrical machine and photovoltaic system education. EE also has a substantial radar and communication infrastructure on the rooftop of the high-rise building (including PARSAX), an antenna measurement room, state-of-the-art (very) high-frequency micro-electronics metrology infrastructure, and a real-time digital simulator for electricity network studies. For Computer Science we have the Insyght Lab and are creating the Social Data Science (SAnDS) lab. CS and mathematics need significant computing facilities and (ultra-)fast connections with other universities and SURFsara.

Needless to say, state-of-the-art research facilities are crucial to performing world-class research and providing an excellent teaching and learning environment, especially for the engineering disciplines. This holds for both undergraduate and graduate students. Further investments necessary to maintain future-proof research facilities are closely connected to the housing issue of the EEMCS faculty. At the time of writing this document, there are still many variables involved, not only in relation to specific EEMCS housing issues, but also regarding TU Delft's long-term real-estate strategy. Plans for redesigning the TU Delft campus are being adjusted in order to lower the housing cost percentage of TU Delft's total lump sum.

Ambitions for the coming years

- Design an attractive working environment for DIAM, ST and INSY in the building on the Van Mourik Broekmanweg that is based, as much as possible, on the EEMCS ambition document.
- Participate in the designing process of the New Education Centre (NEC) that is going to be built next to the Van Mourik Broekman building, and also in the development of the campus square facing these buildings.
- Realize the new Electrical Sustainable Power (ESP) Lab.
- Realize the SAnDS lab for Social Data Science.
- Articulate future housing plans for Electrical Engineering, including the radar lab (with PARSAX) on the roof of the high-rise building, the Cryolab and the EKL cleanrooms.
- Investigate the options for a hardware cybersecurity lab.

International Collaboration

Description of theme

For EEMCS, international collaboration is a means to stay well informed of what is happening in the world, and to strengthen its own capabilities by forming strategic partnerships and alliances. We aim to establish international collaborations with world-class players in focus areas that contribute to our research and education activities. These international alliances involve the familiar construct of the triple helix in which added value arises from collaboration between academic partners, industrial partners, and governmental institutions. Natural focus areas are India (computer science), China (semi-conductors), and Singapore (cybersecurity). For education, the existing partnership with MIT/Harvard needs to be developed further.

Ambitions for the coming years

- Articulate the EEMCS strategy for international collaboration.
- Scale up the Beijing Research Centre (BRC).
- Formalize collaboration with the Indian Institute of Science and industrial partners.
- Formalize collaboration with TNO & Singapore on cybersecurity.
- Extend collaboration with MIT and Harvard for online education.
- Increase collaboration with the Bay Area to stimulate start-ups in Computer Science.
- Formalize and scale up collaboration in applied mathematics with Matheon (via 4TU.AMI)

Organizational Development

Description of theme

In order to improve the faculty's capacity to adapt, the concept of "cloud groups" has been introduced. These groups, consisting of EEMCS employees from a variety of backgrounds, were formed around current topics like formulating values that are typically associated with EEMCS, developing a post-doc policy or articulating an EEMCS vision on the introduction of full English-taught bachelor programmes. EEMCS wishes to implement a sustainable mechanism that enables the faculty to introduce "change" in parallel with "business as usual". This organizational mechanism is referred to as "the adaptive faculty".

Impact and visibility can also be increased by clustering EEMCS research and education activities around themes instead of around the more abstract dimension of departments or sections. This is one of the reasons that the present long-term strategy is presented on the basis of themes rather than departments. The presentation of the EEMCS themes will be supported by a comprehensive communication strategy plan. In addition, the research and valorization activities of the faculty will be streamlined and, if possible, optimized by the ERV team. In the coming years, this initiative (started in 2014) will develop further into an effective calling card for both funding institutions and industrial partners. From an HR perspective, the focus will lie on professionalizing recruitment (including scouting, offering dual career options, and tailor-made start-up packages), developing English proficiency and (personal) leadership skills for (teaching) staff, and improving transparency in the career development policy. Finally, EEMCS wishes to contribute to TU Delft's Open Science policy by being one of the front runners in formulating and implementing a faculty data stewardship policy.

Ambitions for the coming years

- Internalize the EEMCS values in the faculty.
- Implement "the adaptive faculty", i.e. realize a sustainable organizational structure that enables EEMCS to adapt quickly to new developments and to improve its impact and visibility.
- Deliver a comprehensive communication strategy underpinning the EEMCS themes.
- Further develop the ERV initiative into a sustainable asset for realizing EEMCS's valorization ambitions.
- Professionalize recruitment and improve transparency in the career development policy.
- Improve English proficiency and (personal) leadership skills for (teaching) staff.
- Articulate and implement a policy for data stewardship as part of the TU Delft Open Science programme.

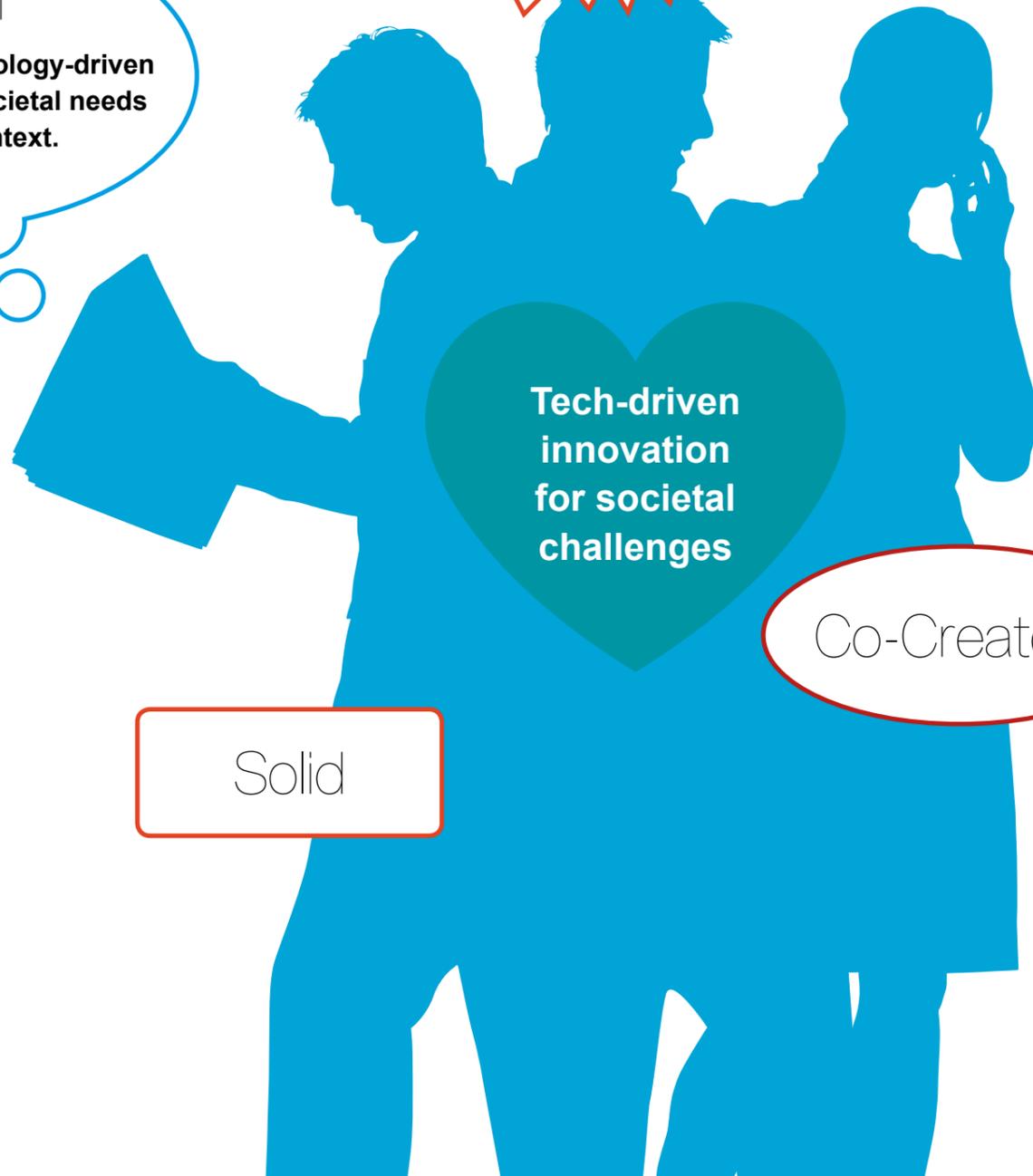


The picture represents a large section of the EEMCS management team and/or cloud group leaders

6 EEMCS values

Vision
We believe in a technology-driven approach to fulfill societal needs in a global context.

Resourceful



Solid

Tech-driven innovation for societal challenges

Co-Creators

Mission
We strive to be the driving force in solving technological problems through expanding and sharing our knowledge in the field of electrical engineering, mathematics and computer science.

Faculty of Electrical Engineering, Mathematics and Computer Science

Resourceful

We are inquisitive, resourceful and inventive. Always looking for new technologies and new applications for existing ones, we combine science and research with practice, training with discovery and the academic world with the world outside. We are not led by existing conventions, but by how we feel things should be done in an ideal situation. And we do everything necessary to get there.

Solid

We provide quality on every level - our engineers, our programme, our research and our solutions. We are a solid partner for young talent, specialists in our field, clients and investors. We want to make a unique and lasting difference. With integrity and wisdom. With boldness and tenacity based on sound knowledge.

Co-Creators

We do things together and in cohesion. We see knowledge sharing as the way to multiply knowledge and experimenting and learning as the way to make progress. We believe in applied science, in multidisciplinary research and in cross-pollination between young and old. Our scientific interest serves societal interest. And that is in everyone's interest.

7 Key figures

Calendar year		2011	2012	2013	2014	2015	2019
Cohort year		2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2019/2020
OCW performance indicators							
Dropout Ba 1 st year	%	27	27	30	29	33	20
BSc pass rate (cohort -4 years)	%	46	47	53	57	57	65
Education							
BSc intake (first TU Delft enrolment)	#	264	326	377	393	440	600
MSc intake (first TU Delft enrolment)	#	105	108	129	179	246	360
Positive BSA	%	64	59	54	54	50	60
Lecturers with English language proficiency	%			68	68	66	80
Research							
PhD candidates	#	437	462	450	447	425	425
PhD pass rate (within 5 years)	%	51	56	46	55		70
Postdocs (fte)	#	56	65	64	61	62	65
Research							
Faculty+ (fte)	#	140	138	140	145*	147*	160
Women in faculty+	%	9	10	15	14	16	21
Women in top scientific positions	#	12	11	8	9	6	11
Finances							
Government funding: indirect & contract funding	M€	39:23	36:21	38:20	36:27**	38:25**	41:31**

* Included in these numbers is 15 fte faculty+ who teach maths "serviceonderwijs". Excluded from these numbers is the 20 fte "docenten" who teach maths "serviceonderwijs".

** Included in these numbers is at least 4.5 M€ for maths "serviceonderwijs", and 2 M€ for Else Kooi Lab (EKL).



8 List of abbreviations

AE	Aerospace Engineering
AI	Artificial Intelligence
AMS	Amsterdam Institute for Advanced Metropolitan Solutions
BME	Biomedical Engineering
BRC	Beijing Research Centre
BSA	Binding Study Advise
CE	Computer Engineering
CEE	3TU Centre for Engineering Education
CEG	Civil Engineering and Geosciences
CEL	Centre for Education and Learning
CryoCMOS	Complementary metal–oxide–semiconductor
CS	Computer Science
CSA	Central Student Administration
CSE	Computational Science and Engineering
CWI	Centrum Wiskunde & Informatica
CYS	Cyber Security
DC	Direct Current
DCE	Delft Centre for Entrepreneurship
DCSE	Delft Institute of Computational Science and Engineering
DDS	Delft Data Science
DIAM	Department of Applied Mathematics
DIAMANT	Mathematic cluster: Discrete, Interactive & Algorithmic Mathematics, Algebra & Number Theory
DST	Data Science & Technology
DSyS	Delft Safety & Security Institute
DUWIND	Delft Wind Energy Institute
EE	Electrical Engineering
EEMCS	Electrical Engineering, Mathematics and Computer Science
EIT	European Institute of Innovation and Technology
EKL	Else Kooi Laboratory
EM	Electromagnetic
EMC	Erasmus Universitair Medisch Centrum
ERC	European Research Council
ERV	EEMCS Research Relations and Valorisation team
ESE	Department of Electrical Sustainable Energy
ESP	Electrical Sustainable Power
EU	European Union
EV	Electric Vehicles
GDP	Gross Domestic Product
GHz	Gigahertz
GPS	Global Positioning System
GQT	Mathematic cluster: Genootschap voor Meetkunde en Quantummechanica
HBO	Hoger Beroepsonderwijs
hDMT	Institute for Human Organ and Disease Model Technologies
HSD	The Hague Security Delta
HTSM	High Tech Systemen en Materialen
Hz	Hertz

IBM	International Business Machines
ICT	Information and Communication Technology
INSY	Department of Intelligent Systems
IPN	ICT Research Platform Netherlands
IT	Information Technology
KTH	KTH Royal Institute of Technology, Kungliga Tekniska högskolan Stockholm
LDE	Universiteit Leiden, Technische Universiteit Delft, Erasmus Universiteit
LUMC	Leids Universitair Medisch Centrum
MARIN	Maritime Research Institute Netherlands
MD	Medical Delta
ME	Department of Microelectronics
MIMO	Multiple-input and Multiple-output
MIT	Massachusetts Institute of Technology
NKI	Netherlands Cancer Institute
NLR	Nederlands Lucht- en Ruimtevaartcentrum
MOOC	Massive Open Online Courses
MRI	Magnetic resonance imaging
MSc	Master of Science
NDNS+	Mathematic cluster: Nonlinear Dynamics in Natural Systems
NEC	New Education Centre
NIRICT	Netherlands Institute for Research on ICT
NWA	National Research Agenda
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
NXP	Next eXPerience
PhD	Doctor of Philosophy
PPP	Public-Private Partnership
ProfEd	Professional Education
PV	Photovoltaics
PWN	Platform Wiskunde Nederlands
QE	Department of Quantum Engineering
QuTech	Quantum Technology
RF	Radio Frequency
RTDS	Real-Time digital Simulator
SAnDS lab	Social Data Lab
SEI	Sport Engineering Institute
SET	Sustainable Energy Technology
SJTU	Shanghai Jiaotong University
ST	Software Technology
STAR	Mathematic cluster: Stochastics-Theoretical and Applied Research
STW	Stichting voor de Technische Wetenschappen
THz	Terahertz
TI	Technische Informatica
TNO	Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek
TPM	Technology, Policy and Management
TU Delft	Delft University of Technology
TUD	Delft University of Technology
UMC	Universitair Medisch Centrum
US	United States
UvA	University of Amsterdam
VDL	Van Der Leegte Groep
3D	Three-dimensional
3TU	The three universities of Technology in the Netherlands
4G	4th generation
4TU	The four universities of Technology in the Netherlands
5G	5th generation

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