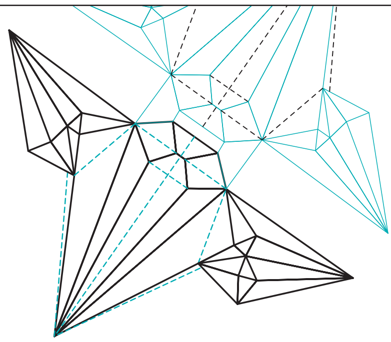
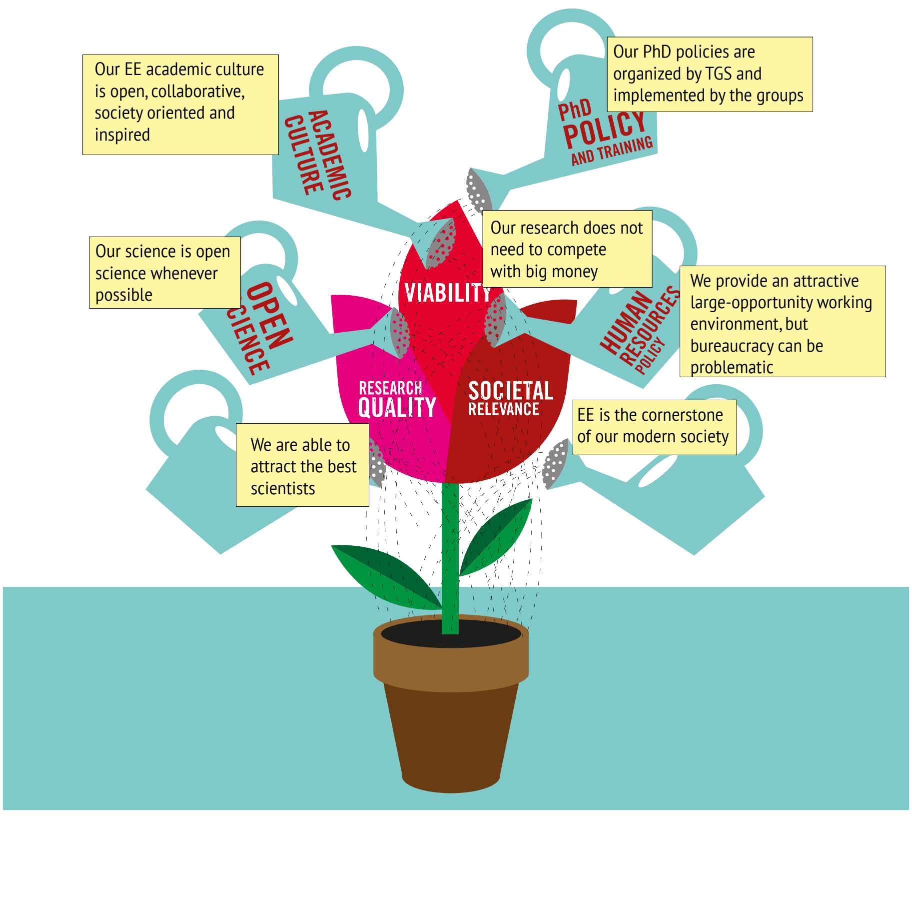
FACULTY OF ELECTRICAL ENGINEERING,
MATHEMATICS AND COMPUTER SCIENCE

SELF ASSESSMENT Midterm Review 2017-2019 ELECTRICAL ENGINEERING





UNIVERSITY OF TWENTE.

SELF ASSESSMENT
Midterm Review
2017-2019

ELECTRICAL ENGINEERING
UNIVERSITY OF TWENTE

1 June 2021

The electronic version of this document has direct links to references and, additionally, links to the list of references at the end of the document, e.g. [2], or to pages, figures or tables in this document itself. You can download the electronic version at:
https://VisitationEE.utwente.nl/pdf/report.pdf or by scanning the QR code:

Additional information is available at https://VisitationEE.utwente.nl/ [1],
or by scanning the QR-code:

This document was prepared in LaTeX in the overleaf.com environment, using the Carlito font.

Contents

Abbreviations and Acronyms

	Groups in Electrical Engineering	Chair
AMBER	Applied Microfluidics for BioEngineering Research	prof.dr.ir. Séverine Le Gac
BIOS	Biomedical and Environmental Sensor Systems	prof.dr.ir. Albert van den Berg
BPR	Biometric Pattern Recognition The BPR group is a part of the SCS group	prof.dr.ir. Raymond Veldhuis
BSS	Biomedical Signals and Systems	prof.dr.ir Peter Veltink
CAES	Computer Architecture for Embedded Systems	prof.dr.ir. Geert Heijenk
DACS	Design and Analysis of Communication Systems	prof.dr.ir. Geert Heijenk
ICD	Integrated Circuit Design	prof.dr.ir. Bram Nauta
IDS	Integrated Devices and Systems	prof.dr. Jurriaan Schmitz
NE	Nano Electronics	prof.dr.ir. Wilfred van der Wiel
PE	Power Electronics and EMC	prof.dr. Braham Ferreira
RAM	Robotics and Mechatronics	prof.dr.ir. Stefano Stramigioli
RS	Radio Systems	dr.ir. André Kokkeler

	Research Institutes
DSI	Digital Society Institute
MESA+	Institute for Nanotechnology
TechMed	Technical Medical Centre

	Graduate Schools
ASCI	Advanced School for Computing and Imaging
DISC	Dutch Institute of Systems and Control
IPA	Institute for Programming research and Algorithmics
TGS	Twente Graduate School

	Other
BMS	Faculty of Behavioural, Management and Social sciences
CMO	Commissie Mensgebonden Onderzoek
CS	Computer Science department
CNPH	Clinical NeuroPHysiology Group in Faculty of Science and Technology
CTW	Dutch for ET: Construerende Technische Wetenschappen
EC	European Credit point
EEMCS	Electrical Engineering, Mathematics and Computer Science faculty (see also EWI)
EE-NL	Electrical Engineering Platform Nederland
ET	Engineering Technology faculty
EWI	Dutch for EEMCS: Elektrotechniek, Wiskunde en Informatica
FAIR	Findable, Accessible, Interoperable and Reusable
IEEE	Institute of Electrical and Electronics Engineers
IGS	Institute for Innovation and Governance Studies
IP	Intellectual Property
KHMW	Koninklijke Hollandsche Maatschappij der Wetenschappen
KNAW	Kominklik Nedelrandse Academie van Wetenschappen
LOWI	Landelijk Orgaan Wetenschappelijke Integriteit / Netherlands Board on Research Integrity
MATH	Applied Mathematics department
MREC	Medical Research Ethics Committee
NPU	Northwestern Polytechnical University, China
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
QAR	Quality Assessment of Research
SCS	Services, Cybersecurity and Safety group
SCNU	South China Normal University, China
STW	Stichting Technische Wetenschappen
TEM	Twente Educational Model
TOM	Dutch for TEM: Twents Onderwijs Model
TOP	Tijdelijke Ondernemers Plaats (Temporary Entrepreneurs' Location)
TNW	Faculty of Science and Technology
T&SP	Training and Supervision Plan University of Twente
UT	University of Twente
WMO	Wet Medisch-wetenschappelijk Onderzoek

Preface

In front of you is the self-study report of the discipline Electrical Engineering of the University of Twente, 2020. In the framework of the regular visitations, as used for university departments in the Netherlands, there is no necessity to carry out a (full-fledged) midterm visitation. However, we, together with our colleagues in Eindhoven and Delft, have taken the opportunity to assess the current state of our discipline, to carefully look back at the, both critical and constructive, remarks as made by the visitation committee in 2017 and at how we have incorporated these comments, as well as what the future of EE in our department(s) will look like. Using the report as a vehicle, we further discussed the developments, chances and threads of our department. Finally we took this opportunity to get experience with the new SEP 2021–2027 report protocol. In this midterm evaluation the self-study report is the final product for EE at the UT. It will be shared with a select number of people to give us feedback on content (and form) but we will refrain from a full assessment by an external committee.

During the preparation of this self-study report we have had multiple meetings with our partners in Eindhoven and Delft. Apart from a renewed acquaintance, this has resulted in the founding of the EE-NL platform, geared towards increased collaboration between the 3(4) TU EE-departments, as well as general promotion of EE in the Netherlands.

Much of how we worked in the last 18 months or so, has been determined by constraints imposed by the Covid-19 pandemic. Despite all adverse conditions, this period has shown the world how Electrical Engineering helps to enable communication, worldwide, to share data and information for the developments of vaccins and to continu important processes in our daily live. It is once more an indication of how much EE contributes to our modern society; an essential contribution that forebodes a bright future for the discipline!

Prof.dr.ir, G.J.M. Krijnen
Head of the EE department

Electrical Engineering in the Netherlands

1 The global landscape of electrical engineering

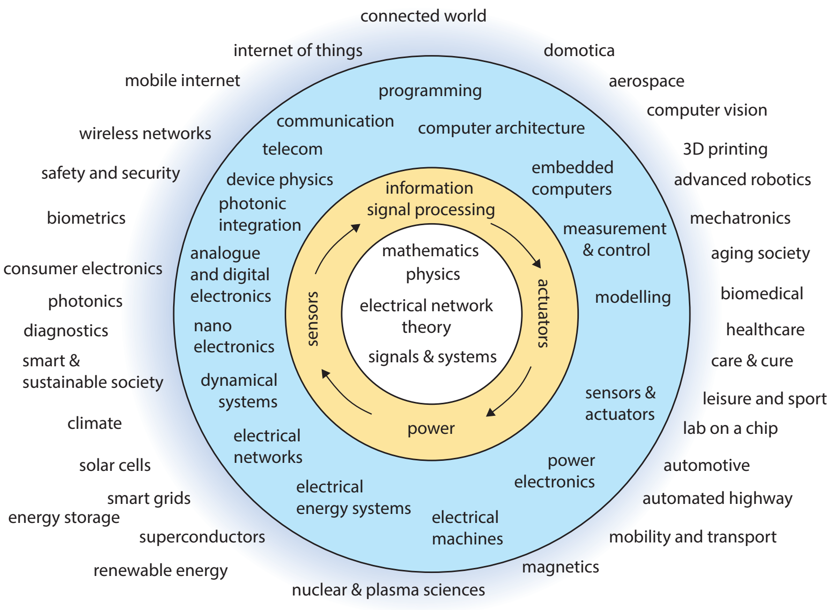
Electrical engineering (EE) plays a key role in our society and global economy. It is directly connected to nine out of twelve potentially disruptive technologies listed by McKinsey [17] in 2013: the mobile internet, the internet of things, advanced robotics, autonomous and near-autonomous vehicles, next generation genomics, energy storage, 3D printing, advanced oil and gas exploration and recovery, renewable energy.
Since the previous review of the EE research the energy transition (wind and solar power, electric cars) has gained momentum. The Corona pandemic has changed the way we are working. Thanks to products directly related to EE working from home is feasible. It may be expected that when the pandemic is over this change will leave a permanent impact.
EE has become increasingly intertwined with other disciplines such as physics, material science, computer science, mechanical engineering, biomedical engineering and chemistry, blending in application areas such as energy, healthcare, mobility and transport, safety and security, vitality and sports.

Domain of EE

The *domain of EE* is best represented by a list of the IEEE professional societies and in more detail by their journals, transactions, letters and magazines. The Institute of Electrical and Electronics Engineers (IEEE) [19] is 'the world's largest technical professional society –promoting the development and application of electro-technology and allied sciences for the benefit of humanity, the advancement of the profession, and the well-being of its (425 000) members'. No research programme can reasonably cover all these subareas explicitly.

Figure 1 describes the domain of electrical engineering at different levels of abstraction. The yellow circle indicates that electrical engineering is on the interface of the physical world, where (electrical) power plays a role, and information processing (in electronics or software). Sensors and actuators couple the two worlds by extracting information from the physical world and after processing this information, via actuators convert the result into actions in the physical world.
The white centre of the figure indicates that EE builds on mathematics and physics, electrical network theory and signals & systems, while power is always directly or indirectly related to the work of electrical engineers.
The blue circle represents the disciplines in EE relevant for realising such systems, while the topics outside the circles show (a selection of) application areas.

Figure 1
The domain of electrical engineering



2 Departmental developments and strategic choices

TUD

No information was provided by the TUD

TU/e

Since 2017, several developments have taken place in the Department of Electrical Engineering at TU/e, but the major driving force behind all is 15% increase of permanent staff we have been able to realize as a result of the Sectorplan funding we received in 2019. Overall, the department and its research have solidified.

THz-domain

cyber-physical system

Closely related to the Sectorplan, we have increased our efforts in a couple of areas of large global importance: the exploration of the last unused part of the electromagnetic spectrum, the THz-domain, where photonics and wireless technology converge; the design and control of a demanding class of cyber-physical systems, electromechanical systems; a joint Dutch effort into developing next-generation design methods for electronics, evoked by the increasing difficulty of reaching design specs by miniaturization; creation of a common framework for signal processing technology underlying health applications.

Photonic Integration Technology Center

The faculty has continued its cooperation with industrial and societal partners, especially TUD and UT. It is gradually moving towards larger funding opportunities, for example in the areas of photonics, energy, high-tech systems and artificial intelligence. In these activities, our EE-Centers are essential, but also the more recently established university institutes. To facilitate fundamental knowledge transfer to applications, we set up the *Photonic Integration Technology Center* (with UT and TNO) and the *Mission 10X* initiative (with UT, Radboud University and IBM).

Artificial Intelligence Engineering Systems

The faculty has taken the lead in developing a master program on engineering artificial intelligence, called *Artificial Intelligence Engineering Systems*, a program in which 7 departments cooperate. In a 4TU-project on outreach to increase student diversity, the EE-discipline is a pilot. Online education developments have been accelerating due to Corona, providing valuable experiences for enhancing our education.

UT

Power Electronics

Supported by the funding from the sectorplans, the UT/EE has started two new groups.
Completely new is the *Power Electronics* group. The research focus of the group is on battery electronics, conducted and radiated electromagnetic interference and power electronic packaging as well as on physical layer of communication systems. One special theme of the program is small solar systems with battery storage to provide off-grid electric services to 3 billion people living in energy poverty. It is a challenging research field because it not only requires innovative and reliable technology, but the solutions need to be sustainable from a socio-economical point of view.

Radio Systems

The former Telecommunication Engineering group has been converted into the *Radio Systems* group. The research covers a wide range including designing physical layer (PHY) for wireless communication systems, signal processing algorithms, radio propagation and channel modelling and antenna design. In addition to the theoretical components, we are interested in practical aspects. That is why, digital implementation of the signal processing algorithms, prototyping communication systems using Software Defined Radios (SDRs), building and testing the designed antennas and practical channel measurements are also integral part of the research work in our group.

UT campus infrastructure

Research institutes

The *UT campus* infrastructure and the neighbouring Kennispark offers a.o. the Nanolab, the Design lab, the Techmed Centre, the Gallery and numerous companies, all of which strongly contribute to the identity of electrical engineering at the University of Twente and offer many chances. In the DesignLab research and education combine in an environment that is open to society both on the national and international level. The Nanolab technology enables fundamental breakthroughs such as in the BRAINS centre. The Techmed centre hosts numerous connections to healthcare such as the TOPFIT Citizenlab that brings together citizens, healthcare professionals and companies. The Gallery offers an on-campus bridge between companies and researchers. Organisation-wise, the *research institutes* MESA+, Techmed and DSI facilitate easy multidisciplinary cooperation across the boundaries of the faculties. This dynamic, interconnected and open-to-society atmosphere strongly benefits the electrical engineering department. For the future, UT-wide plans exist to invest in integrated photonics together with Lionix International, in which EE will participate.

UT-continued

Open UT culture

Plans are advanced for a robotics and AI centre that will bring together researchers, companies and students in a highly synergetic environment. The open and dynamic research environment combines perfectly with two educational pearls of Twente, which are the recent bachelor study Create and the master study Technical Medicine. A master study robotics will kick off in 2022 with an important contribution from EE. Electrical Engineering in Twente sees this cooperative, connected and *open UT culture* as the cornerstone of its success.

3 Sectorplan

Sectorplan Techniek

Sectorbeeld

Sectorplan Committee

The *Sectorplan* is a Dutch government initiative to strengthen the foundations of research in a specific set of disciplines. The first *Sectorplan* (2007) covered the disciplines of Physics and Chemistry. In November 2017, the Ministry of Science and Education decided to engage in two follow-up *Sectorplans*, one which would cover four beta-disciplines and one, the *Sectorplan Techniek*, to strengthen three engineering disciplines: Electrical Engineering, Mechanical Engineering and Civil Engineering.
To realize the plans, there was an associated structural budget for new permanent scientific staff, amounting to 17 M€ per year for the three selected technical disciplines. This allowed to appoint about 100 new staff, to be distributed over the various faculties.
As a preparation, all pertaining universities were asked to describe these disciplines, their research subjects, the way in which they were organized, their cooperation and their outlook. The resulting document, the *Sectorbeeld* [14] (in Dutch), was the basis for the actual plans of the disciplines to strengthen their research and disciplinary basis. The plans, one for each university, detailed the research prospects up to the level of concrete necessary positions in the first months of 2019. The plans were evaluated by a special committee, the *Sectorplan Committee*, and finally approved by the Minister in June 2019.
In the meantime, the involved universities started their hiring processes, and these continue to date. At the time of this writing (March 2021), almost all vacancies have been filled. The lengthy hiring process was partly due to significantly salary differences, with respect to industry as well as neighbouring countries, as to the additional Sectorplan aim to realize a serious shift in the gender balance. Of course, the Corona-crisis resulted in additional complications. The results, however, are very satisfactory, which was helped by being able to offer solid starting packages.
Although the Sectorplan-positions are permanent in principle, the Ministry and the Sectorplan Committee evaluate progress on a regular basis. The Committee is planning a yearly visit to all universities, to keep up with the developments and the research strengthening. They will report to the Minister in 2024, to make the budgets and positions final.

4 Reactions on the comments of the committee of the Review 2011-2016

Electrical Engineering Platform Nederland

Many of the comments of the committee stimulate us to develop plans together with the three EE departments. The recommendations range from “Roadmap for EE on a discipline level” to “doing a proper Benchmark together”. Plans for a benchmark visit to Chalmers University of Technology are being made. Most of the other recommendations can be realised by reviving the ‘E-kamer’. When there were still 3 faculties of EE, the E-kamer met every half year to do exactly what is needed now. The delegations of each university consisted of the dean and the vice deans for research and education. Strategic choices were discussed in an open atmosphere. After the introduction of the faculties EEMCS in Delft and Twente the E-kamer slowly disappeared from the agendas.
We realise the importance of regular meetings of the discipline EE. This again became clear during the formulation of the sectorplan Techniek. Setting up this plan required agreements and common plans for stimulating focus points in all three EE departments. Good contacts and making common plans to stimulate EE on a national level is also the wish of the Sectorplan Committee. Therefore, the three EE departments have decided that such an E-kamer new style must start again. A few meetings of the ‘*Electrical Engineering Platform Nederland*’ have taken place recently.
Representatives of the 3TU EE disciplines recently started to form an E-kamer new style. The formulated mission reads:

1. Establishment of an EE community in the Netherlands to improve the visibility of EE and promote the notion of the importance of EE for relevant societal parties.

EE-NL

2. To contribute to societal challenges by common, 4TU-EE concerted actions to efficiently use and, when needed, acquire needed infrastructure. *EE-NL* is the name given to this platform.

Activities will include: to improve the visibility of EE in the Netherlands, to collaborate in and align common project proposal to improve success rates in larger project calls (NWO Zwaartekracht, Perspectief), to optimise (proposals for) infrastructure sharing and to collaborate in education with respect to content, influx and diversity of students. Because the management structure at the 3 TUs is different now, the composition of the platform will be different; current ideas point to a combination of a management team with a platform chair, three representatives of each TU and a secretary, as well as a board consisting of the deans of the faculties of the 3 TUs in which the EE disciplines reside.
As a precursor to the revived ‘E-kamer’ the EE disciplines of the 3 TUs have collaborated on a few subjects related to this midterm visitation self-study report and will continue to do so in preparation for the full term review in 2023, e.g. in formulating adequate answers and actions related to the previous 2016 full-term visitation.

The self-evaluation starts with a brief presentation of the research unit. Main characteristics, important organisational features and changes over the past years are presented.

1 Introduction

1.1 Introduction

The strength of the UT lies in the collaboration between the various disciplines. In the research institutes the UT connects technology (high tech) to human behaviour and social relevance (human touch). Before 2017 research was organised through scientific institutes. It were the prerogatives of the institutes to develop strategic lines for research and govern over the research in the research chairs. However, in the reporting period (since 2017) this model was changed considerably and governance is transferred to the faculties. Given the previous situation all research chairs of EE are participating in one or more research institutes.

DSI
(BPR, BSS, CAES, DACS, ICD,RS,PE, RAM)

The description of the institutes is based on the texts of the various websites ([3], [4], [5])

The *Digital Society Institute* (DSI) [3] performs scientific research in technology that is essential for digitalisation, on methods and techniques for integrating digital technology in our environments, and in how we can come to intelligent, well-informed decision making. An important aspect of their mission is to conduct research that has a positive impact on society.

"We live and work in the exciting age of digital transformation. The University of Twente's mission as a people-first university of technology places us in the crossfire of digital advancement and the disruption it can cause. As scientists and tech pioneers, our task is to drive digitalization. In close cooperation with all our stakeholders. Next to other institutes and faculties at the University of Twente, these include business & industry, government, NGOs and knowledge institutes. As a partner in regional, national and international ecosystems, we offer the knowledge, education and infrastructure for the development of successful solutions and products. In doing so, we focus on five themes: Data Science & AI, Smart Industry, eHealth, Robotics and Cyber security. We boost innovation by delivering scientific knowledge for real-life solutions that have societal and economic relevance. Our research focuses on natural, societal and industrial challenges, which serve as starting points for our way to work and have one common denominator: digital technologies. Our work contributes to solving three main challenges."

TechMed
(AMBER, BIOS, BSS, RAM)

For EE, TechMed offers access to clinical institutions and facilitates applications in real-world settings.

The *Technical Medical Centre* (TechMed Centre) [4] is a leading Innovation Hub impacting healthcare by excellent Research, Innovation and Educational programmes. It is equipped with state-of-the-art infrastructure, ranging from research labs, preclinical testbeds and simulated hospital environments.

"Technology is a tool to enable high-quality healthcare. Not only for diagnosis and treatment, but also for improving the quality of life and to stimulate independent living. We strive to have a significant impact on society, both by scientific excellence as well as by linking fundamental research to clinical applications, from the nano to the global scale. Ultimately, we bring our technology to the clinic or to the home environment. For this purpose, it is imperative to have close working relations with clinical and industrial partners."
"In our mission to impact society, we stimulate entrepreneurship and enable (new) companies to grow within our regional Novel-T ecosystem. We collaborate with industry, hospitals, governments and insurance agencies on the development of new solutions for healthcare."

MESA+
(AMBER, BIOS, IDS, NE)

For EE, MESA+ offers material research for future electronic components, sensors and actuators.

MESA+ [5] is one of the world's leading research institutes on nanostructures, nanomaterials, nanosystems and nanodevices. Embracing a cross-disciplinary approach and benefiting from the NanoLab - infrastructure that ranks among the very best on the globe - over 500 researchers deliver high quality, competitive and frequently ground-breaking research. The results are evident in their numerous publications as well as in various high-profile achievements.

"We focus on key enabling technologies - photonics, fluidics, hard materials, soft materials and devices, combined with responsible research & innovation - and the convergence of these to realize disruptive innovations in the areas of most societal challenges. Our main contributions are on the Health, ICT and Sustainability areas.

MESA+ actively seeks for collaboration with external partners providing an excellent setting for consortium formation. Next to our excellent scientists and facilities, we offer a strong regional ecosystem that creates the breeding ground to let ideas blossom and grow to relevant, successful solutions and businesses."

In Figure 1.1 the 11 EE groups are shown in a circle, illustrating how neighbouring groups seamlessly cover our selected fields in EE. It can be seen that EE is right at the intersection of the three main institutes present at the University of Twente, giving us a central and connecting role in our university research. The research of EE should be reviewed in the context of multidisciplinary cooperation in these research institutes.
It is our belief that EE is a corner-stone of modern society, e.g. as witnessed in the current pandemic and the role EE technology plays in the resilience of the functioning of our society (communication, health, etc.). With the activities chosen by our EE discipline we can optimally contribute to developments in this field and to society, and with the means that we have at our disposal.

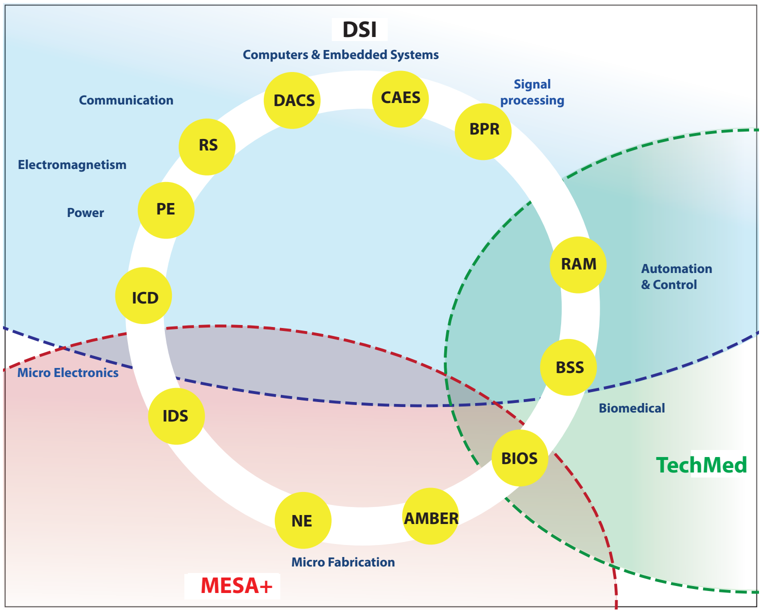


Figure 1.1
Connections to other disciplines via the institutes DSI, TechMed and MESA+

See page v for the list of abbreviations

1.2 Financing

In the Netherlands we distinguish three sources of funding: the 1st-, 2nd- and 3rd flow of money:

1st flow – *Direct funding* from the ministry of education
2nd flow – *Research grants*, obtained in competition from national funding agencies (NWO, STW)
3rd flow – *Contract research* with industry and EU projects.

Figure 1.2 shows how the 1st, 2nd and 3rd flows of money reach the research groups.

Figure 1.2
Financial Flows (2020)

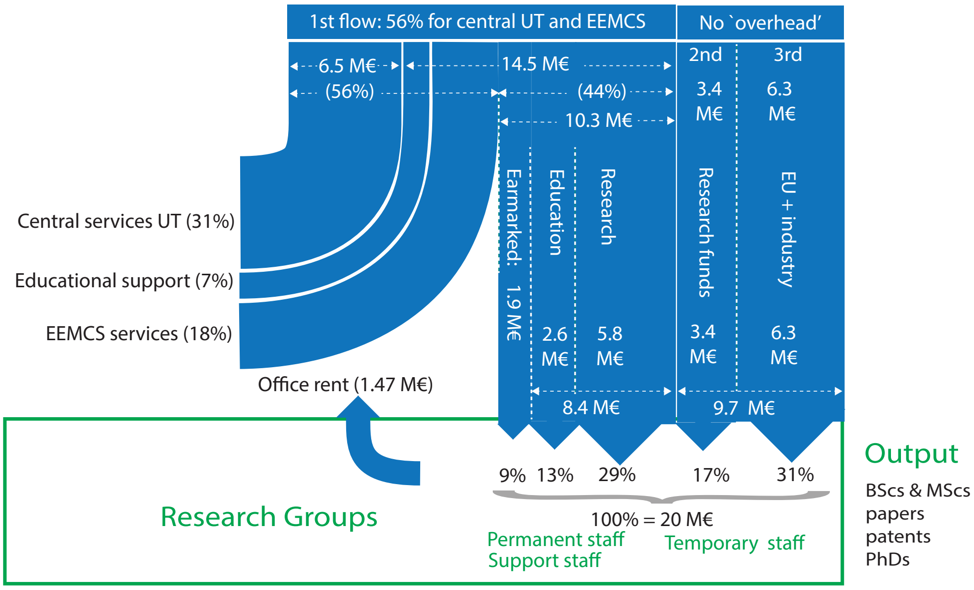
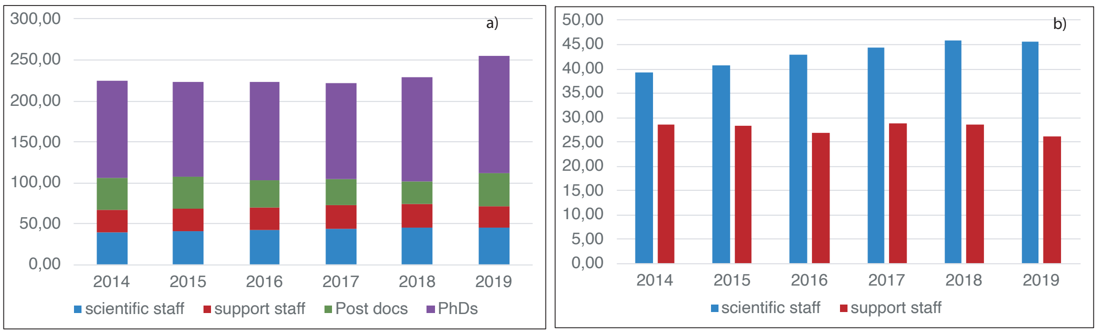


Figure 1.2 shows how the various money streams reach the groups. The budget of EE out of the 'first money flow' is 14.5 M€. Assuming that EE has an equal share in the central services of the UT, the contribution of EE to these central services is estimated to be 6.5 M€ or 31% of the total bruto budget of EE. After subtracting the payments to educational support en services of EEMCS, 10.3 M€ goes to the groups (8.4 M€ related to education and research + 1.9 M€ 'earmarked'). The earmarked money consists of 1.4 M€ for the sectorplan positions, 300 k€ 'zwaartekracht' funding, plus 220 k€ for the Max Planck institute. In addition to the total net budget of 10.3 M€ of the first money flow, EE realises an income of 3.4 M€ from research funds (NWO) and 6.3 M€ from the EU and industry.

In 2013 we had a reorganisation in which about 25% of the permanent staff was made redundant, leading to a reduction of the expenses. Since 2014 there has been an 8% reduction in the support staff, but a 16% increase in the scientific staff. Figure 1.3a shows that in 2019 we attracted more PhD students than the years before. In figure 1.4 we see, as could be expected, this correlates with an increase of the funding from contract research.

Figure 1.3
Development of the staff (research FTEs) (based on the data of Table A3.a)



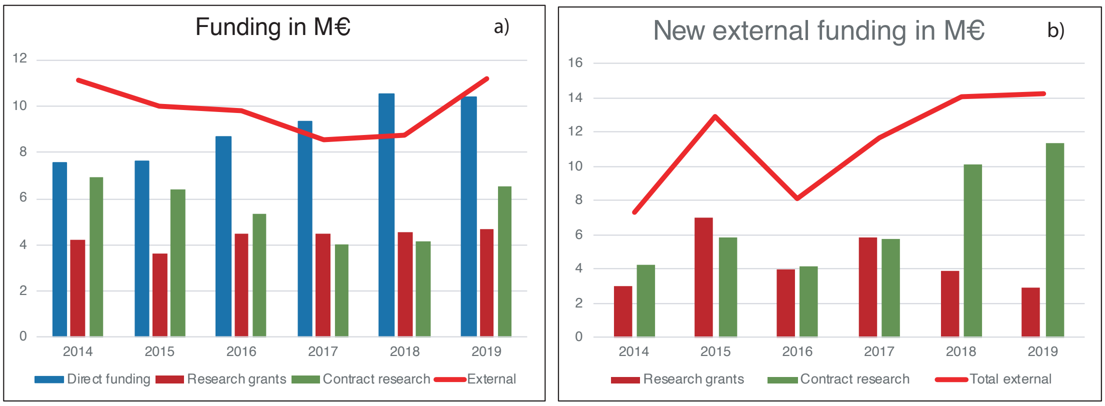


Figure 1.4
Funding: in most years more than 50% external

Direct funding has 25% increased

Increase of over 80% in external funding

2nd money stream research

In Figure 1.4a we see that direct funding has grown over 25% in the last 5 years, a situation very much welcomed in the EE discipline. The increase can be mostly attributed to the various strategic investments on national level and correlates well with the increase of permanent faculty staff in EE. However, little of this money, except for the strategic programs as carried out by the EEMCS faculty, e.g. the theme-team call, ends up in actual new research (projects). To a great extent the latter are depending on the 2nd and 3rd money streams. Figure 1.4b shows that from 2014 - 2016 external funding first increased by about 50% in 2015, to decrease again with the same amount in 2016. We attribute this to the earlier-mentioned reorganisation. From 2016 onwards we see an *increase of over 80% in external funding* in the years 2017 - 2019. However, most of this increase is due to contract research, including EU projects. At the same time we see that a decline in research grants by about 50% such that these grants account for only 21% of the total external funding. Our suspicion is that this partly has to do with the financing of the *2nd money stream research* (e.g. NWO, FOM, ZonMw) which only covers additional cost but no overhead or hardly any salaries of permanent personnel. In combination with the approximately 10 k€ overhead cost per year per person, as imposed by the EEMCS faculty, it implies that this type of grants is financially far less interesting than contract research. Though financial motives should never determine our choices for research subjects and we should be lead by academic interest only, we still would like to plea for an improvement of the situation regarding such funding. After all, it would be a shame when we would (have to) turn away from programmes provided by national funding agencies, solely because of financial motives.

1.3 Human Resources policy

Female professors

The goal of the faculty of EEMCS for 2025 is to employ 20% *female full professors* 20% Associate and 35% Assistant professors. At present these numbers are 12% full professors 13% Associate and 30% Assistant professors. To achieve this goal it will be necessary to fill 50% of all vacant positions with female staff. Currently the faculty EEMCS is looking into possibilities to prioritise female applications.

Junior scientists

Technical support staff

Regarding a balanced age distribution we actively monitor the quality of our *junior scientists*, e.g. not only by the direct superior but also by a yearly meeting in which the quality of all faculty is discussed with all chairs and personnel from the HR department. This way promising junior faculty is identified and appropriate growth paths can be determined and supported. On a side note, one of the insights evolving from these meetings is that the VSNU University job classification system (UFO) actually provides few growth possibilities for *technical support staff*. Certainly in current times of shortage of technical support personnel we look into tailor-made creative solutions on individual level to improve this situation.

PhD students

The *PhD students* form a crucial part of our scientific activities. The Twente Graduate School gives a clear framework for our PhD policies. However, we value an intensive coaching of our PhD students, e.g. by having regular progress meetings. Through early attendance of conferences, participation in specific courses (e.g. Our Future Leaders, as provided by the Recess College) and other activities we aspire to educate and train the next generation of top and leading scientists.

Work-pressure

More generally we see that our EE discipline forms no exception in terms of *work-pressure* and working hours as experienced in academics in the Netherlands. Especially the increasing administrative duties seem to take their toll in the efficiency of our work. Though this is a problem that should be addressed on a large NL scale, we feel that the size of our discipline and the open and the collegial atmosphere help in keeping things in bound. We value this aspect of our collaboration and feel that, together with our attractive infrastructure, it also helps us to interest new talents to come to Twente.

1.4 Procedures for issues regarding scientific integrity

The discipline of Electrical Engineering adheres to university-wide policies and procedures for scientific integrity. The UT website [6] and the links provided there, explain in detail how the UT deals with issues concerning scientific integrity. The University of Twente subscribes to the guidelines for scientific integrity, as specified in the VSNU policies and procedures in the Netherlands Code of Conduct for Research Integrity [7]. The European code of conduct [8] and the Singapore statement on research integrity [9] are also relevant as well as the advice of the KNAW about correct citations [10].

Scientific Integrity Complaints Procedure

The Executive Board of the UT established the *Scientific Integrity Complaints Procedure* in order to protect and guarantee scientific integrity. This procedure provides a system for reporting and dealing with possible violations of scientific integrity. This procedure is consistent with the national LOWI (National Body for Academic Integrity) regulations.

Confidential advisor for scientific integrity

The first point of contact is the university's *confidential advisor for scientific integrity*, emeritus prof.dr.ir. O.A.M. (Olaf) Fisscher. Possible violations of scientific integrity as well as any follow-up steps can be discussed with him in all confidence. Actual reports about (possible) violations of scientific integrity are dealt with by the appropriate committee, comprised of:

– Prof.mr.dr. M.A. (Michiel) Heldeweg, BMS Faculty (chair)
– Prof. dr. ir. L. (Leon) Lefferts, S&T faculty
– Prof. dr. ir. P. (Piet) Bergveld (emeritus)
– Prof.dr.ir. G.J. (Geert) Heijenk, EEMCS Faculty

Advice of the committee

The *advice of the committee* is sent to the Executive Board of the UT for further action as well as to the LOWI. The Executive Board determines its opinion on the complaint and takes appropriate measures. Attention to scientific integrity is given on various levels. In the first module of the EE curriculum research integrity and avoiding plagiarism are already taught. Scientific integrity also receives explicit attention during the BSc and MSc projects and in the supervision of PhD students. When writing their theses, all students are taught how to deal with quotations, citations and references. Members of the department witnessed multiple breaches of scientific integrity by researchers outside the UT, and responded to these according to the contemporary code of conduct.

All PhD theses of EE are being checked for plagiarism.

1.4.1 The ethics protocol of the faculty of EEMCS

Medical Research

Research with human subjects must undergo a medical-ethical review if it falls under the *Medical Research* Involving Human Subjects Act (WMO). For the medical-ethical review the University Twente collaborates with an accredited MREC, the CMO Arnhem-Nijmegen (in Dutch), and support is offered by the UT Techmed centre.

University-wide research ethics policy

The University of Twente has adopted a *university-wide research ethics policy* for the ethics assessment of research which does not fall under the WMO act. Ethical review is conducted and facilitated by 4 domain-specific ethical committees: Humanities and Social Sciences, Natural Sciences and Engineering Sciences, Geo-Information Sciences and Computer & Information Sciences. A web-based tool is in preparation to assist students and researchers to submit their research proposals to the relevant committees for approval. The committees consist of representatives of the groups in which this kind of research is actually performed. The groups involved have submitted certain ‘standard research’ topics in the protocol text, referring to research that has been carried out previously in the group on a more or less regular basis. The full committee assesses the standard research topics once. A standard research proposal may be assessed in a fast-track procedure. This means that the committee member of the department is authorized to make a positive assessment of the ethical permissibility of the research proposal under consideration. If the member of the department is him/herself involved in the proposed research, however, the proposal must be submitted to the full committee.

1.4.2 Data policy

Open data

Open data and related research-data policies are gaining importance in academia. In 2017, at the national level, a National Plan Open Science [36] was presented by all major Dutch research organizations. Already in 2015, an overall research-data management policy was established by the UT, updated in 2018. The UT policy statement Shaping 2030 formulated that in support of the Open Science transition, 100% Open Access publication is the aim to be reached already in 2023. Preferably this should be immediate open access publications, and if necessary, after 6 months via UT research information website. At present (2020) 65% is already open access. Tools such as the UT Open Access website [11] help researchers in this process. Shaping 2030 [13] also established FAIR [12] data as the new norm for UT researchers. The university-wide data-management policy serves as a starting point for tailored data policies of UT faculties, institutes, and research groups.

UT-wide RDM

To further the implementation of the research data management (RDM) policy, a *UT-wide RDM* project was started in 2019. Within this project a data steward was hired to provide direct practical support on RDM for researchers within EEMCS. In 2021 the RDM project will result in the start of a Digital Competence Center (UT-DCC) at the UT, with funding from the Dutch Government. The goals for the UT-DCC are:
Coordination/organization of Data Stewardship and ICT research services Knowledge and advice centre for Open Science, FAIR data/software [12] within the UT Knowledge and advice centre for digitization of research and related ICT facilities Node in a network for open science, data and digitization of research and ICT facilities both inside and outside the institution

EEMCS

In 2019 the faculty *EEMCS* formulated a tailored research data management policy, which is a refinement of the UT-wide policy. In turn several individual groups already have or are in the process of formulating further refinements in the form of practical guidelines and workflows for the handling of research data. The guiding principles in all of these are scientific integrity and FAIR data.

Twente graduate school

The *Twente graduate school* offers a compulsory course on Research Data Management for all PhD-students for which the data stewards function as trainers. Subjects in the course are: management of data for verification and reuse, the value of research data as scientific output of one’s research, awareness of legal issues in the handling of research data and writing a data management plan (DMP).

In this chapter we describe our mission and the main strategic aims of the past three years. This description regards its contribution to scientific knowledge, as well as its contribution to society.

2 Mission and strategic aims of the past 3 years

2.1 Mission

Given the grand challenges in ICT, healthcare, robotics, energy transition, transport, security, and so on, we see a central leading role for the field of electrical engineering. Electrical engineering is application oriented while it has a lot of synergy with other domains, making EE a key enabler to address these challenges. Through our graduates and industrial collaborations, we address technical problems from an EE perspective.

Mission

Our research *mission* is to find fundamentally new solutions to practical problems in society. In this effort, we involve and train young scientists to become capable of taking a leadership position within the broad spectrum of topics of electrical engineering.

2.2 Vision

Bits meet Nature

Embedded System

The field of electrical engineering is the place where '*bits meet nature*'. In this context 'nature' is the real world we live in with physical activity and information. The virtual world of 'bits' is related to pure information carried by electrons in an electronic circuit. From this vision EE takes a central role in almost every modern digital system. Central in such a system is a computing core, which is built in integrated circuit technology, in which electronic circuits are processing analogue and digital information, resulting in a so called '*embedded system*''. Such a general computing system is illustrated in Figure 2.1. In order to be able to connect such a computing system to 'nature', sensors, actuators, and often a feedback control system and communication are required, while for connection of the electron world to the world of 'bits' dedicated software applications are needed, operating in synergy with the hardware. With our 12 research groups in EE, we cover key areas of such a system, as illustrated in Figure 2.1.

2.3 Research lines and objectives in the last three years

Starting at the core of EE, we have the following activities in the various domains of EE:

Microelectronics

The Nano Electronics (*NE*) group of *prof. Wilfred van der Wiel* is focusing on disruptive new electronics, going beyond the boundaries of traditional disciplines. It plays a central role in the development of neuromorphic electronics as cofounder of BRAINS, the Center for Brain-Inspired Nano Systems, and also quantum electronics with QUANT, the Center for Quantum Nanotechnology Twente. With this type of research, often done under cryogenic conditions we learn to better understand the fundamental behaviour of new materials and new structures.
The Integrated Devices and Systems (*IDS*) group of *prof. Jurriaan Schmitz* conducts research on materials and devices for upcoming generations of microelectronics, including integration and reliability aspects. The program is conducted in close collaboration with semiconductor equipment industry and integrated circuit manufacturers.
The IC Design (*ICD*) group headed by *prof. Bram Nauta* is focusing on the design of analogue and RF interfacing circuits with a main application currently in wireless communication. ICD uses industrial available IC technologies, enabling excellent transfer of know-how to industry.

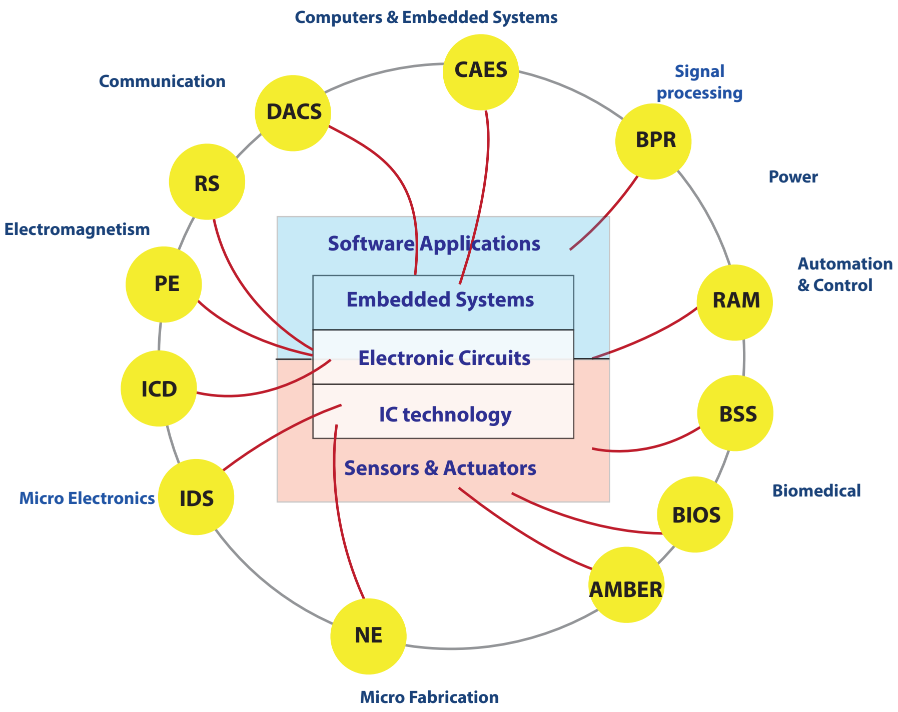


Figure 2.1
Electrical engineering, where bits (information/software - light blue) meet nature (hardware, the physical world - pink)

Electromagnetism	One part of our work on electromagnetism occurs in the Radio Systems (*RS*) group, headed by *dr. André Kokkeler*. The group focusses on antenna systems, radio propagation- and channel modelling, and signal processing. Another part takes place in the Power Electronics (PE) group headed by *prof. Braham Ferreira*. The research in the PE group focuses on battery electronics, conducted and radiated electromagnetic interference and power-electronic packaging as well as on physical layer of communication systems.
Communication	In addition to the research on reliable wireless communication in the RS group, the Design and Analysis of Communication Systems (*DACS*) group headed by *prof. Geert Heijenk* also works on communication. This group is focusing on the design of dependable cyber-physical systems, in which communicating systems are fully integrated in an enclosing physical system, providing services to the outside world. Application fields include mobility, energy and safety and security.
Computers & embedded systems	The Computer Architecture for Embedded Systems (*CAES*) group, headed by *prof. Geert Heijenk* (interim) develops and applies techniques for energy-efficient, real-time and reliable embedded systems. Applications powering this research vary from integrated circuits to smart grids.
Signal Processing & Imaging	Our signal processing is carried out in three groups. The first group is biometric pattern recognition (*BPR*) headed by *prof. Raymond Veldhuis* with research in machine learning for biometric recognition, including (forensic) fingerprint and face recognition, vascular pattern recognition, and research in privacy protected biometric recognition, and sensor development. The medical field is covered by *prof. Kees Slump* who is part of the Robotics and Mechatronics (RAM) group. Here the focus is on medical imaging techniques and image-guided navigation in the body. The third group is the BSS group (see below under Biomedical).
Robotics, automation & control	The Robotics and Mechatronics (*RaM*) group, headed by *prof. Stefano Stramigioli* and *dr. Jan Broenink*, is active on both fundamental and application-driven topics in the field of robotics. Modelling, dynamical systems, control, sensors, actuators, real-time (embedded) software, computer vision, and systems design are the research topics. We develop novel fundamental paradigms and physically-based methodologies which we then translate from the Lab into demonstrators and prototypes using, among others, the extended additive manufacturing facilities we have: 17 3D-printers. The area of robot application is mostly in healthcare, and inspection and maintenance. The research is embedded in the TechMed and DSI Institutes.

Biomedical

Our biomedical work spans research from body-sized systems to microfluidics. The Biomedical Signals and Systems (*BSS*) group headed by *prof. Peter Veltink* performs research (in a home or clinical setting) on smart sensing, selective actuation, neuromodulation and persuasive coaching technologies. The *BIOS*-Lab on a chip-group headed by *prof. Albert van den Berg has* pioneered micro- and nanofluidics. The group bridges the gap between users from physical, chemical, medical and life-science fields and demonstrates the potential of 'Lab on a Chip' in biomedical and process industry, environmental applications and organs on chips. The *AMBER* group, led by *prof. Séverine Le Gac*, aims at the development of functional devices for pharmaceutical, biological and medical applications through the exploitation of micro- and nanotechnologies, and their combination with biological materials (cells, cell aggregates, etc.).

Sensors & actuators

Besides the microfluidics work in the BIOS and AMBER groups, part of the IDS group, headed by *dr. Remco Wiegerink*, carries out research on micro- and nanomechanical devices and systems, with a focus on microfluidic handling systems and sensors for force, acceleration and fluid flow. In the field of embedded sensing, *prof. Krijnen* of the RAM group investigates fabrication, design and application of 3D-printed sensors integrated in robotic, prosthetic, and orthotic devices. Emphasis is on mechanical and biopotential (sEMG) sensing.

2.4 Research environment and embedding

As indicated in Chapter 1 (Figure 1.1) all our research is carried out in the multidisciplinary environment of the research institutes of the UT. The participants in the research institutes meet on regular basis to discuss research related plans. The chair holders of the department of EE meet every month, to discuss topics related to the EE BSc and MSc programmes as well as research and organisational topics. A few times per year the chair holders and the faculty board of EEMCS meet during a dinner where topics important for EEMCS as a whole are discussed. This matrix structure creates a research environment with sufficient critical mass to be a major player in the Netherlands and Europe and stimulates multidisciplinary cooperation with groups outside EE. Most groups have regular contacts with their 4TU counterparts.

2.5 Role of the institutes

With the new roles for the research institutes and faculties the activities of the former have changed considerably. Where previously the institutes dealt with all research matters there now is focus on facilitating and promoting collaboration between the research chairs, in order to maximise research opportunities and efficient use of shared infra-structure, and forming a clear recognisable point of contact between the research groups and external parties. In some cases centres are established to further support this goal, e.g. the *Brain-inspired Nano Systems (BRAINS) Centre* in which the Nano Electronics group plays a leading role. Via MESA+ also the centers '*Quant*' (the Centre for Quantum Nanotechnology Twente, with an important role for NE) and together with TechMed the '*Organ on Chip Center Twente*' (with an important role for BIOS) were founded

Brain-inspired Nano Systems (BRAINS) Centre
Quant
Organ on Chip Center Twente

The role of the research institutes has become more strategic. As an example, DSI is active in bringing together the research activities in the domain of Artificial Intelligence, forming one clear point of contact to the external world and promoting the UT as an important player in the field. The MESA+ institute coordinates and promotes nano- and microtechnology at the UT, plays the the central role in the evolution and management of the Nanolab cleanroom infrastructure and ties its infrastructure with other labs in the Netherlands. It is instrumental in bringing together groups around research focus and initiatives. The TechMed center [4] has opened the *TechnoHal* in 2019 where it provides modern spaces for research and education in the field of biomedical engineering and health and it is aspiring to be "*a leading Innovation Hub impacting healthcare by excellent Research, Innovation and Educational programmes*". It initiates common research proposals, builds a community through extensive health related events (The so-called *TechMed events*) and facilitates small grass-roots initiatives through concerted actions with the regional hospitals and educational institutes. Examples are the Pioneers in Health Care (PiHc) vouchers for combined technical–medical research for one year projects, and the Turbo grants. The Turbo grants, are aimed at small, short, collaborative

TechnoHal
TechMed events

projects between the UT and Radboud UMC in order to facilitate limited investigations, facilitating or strengthening common research proposals.
The institutes are actively involved in the granted 'Groeifonds' proposals QDNL, with 150 M€ voor NanoLabNL, AI (DSI) and the proposal in preparation MedTech and NxtGen.

2.6 EE in the faculty of EEMCS

Sector plans

The three disciplines Electrical Engineering, Mathematics and Computer Science form the foundation of EEMCS. Important matters such as visitations take place within the disciplines. The faculty therefore opts for a certain autonomy, whereby substantive choices can be made within the disciplines. The disciplines thus have the space to partly determine the distribution of research budgets. A good example of this are the recently-formulated '*sector plans*' that have been designed by the disciplines themselves. The ambitions and investment agendas set out herein, form an important part of the disciplinary and faculty research agendas for the coming six years. Supplemented with the research agendas for the non-sector plan research areas this forms the agenda for the entire discipline.

The three EEMCS disciplines are also strongly intertwined. EE transduces input from the physical world to the electronic domain and manipulates the data in electronic form using algorithms designed in CS, depending on mathematics to make the decisions. The design and development of new electronics as e.g. in the BRAINS center (EE) needs the development of new mathematical tools (M). The design and analysis of secure and dependable communication systems needs an integrated design of hardware (EE) and software (CS). In a comparable way, energy-efficient and reliable embedded systems can only be developed with concerted efforts in developing hardware and software.

2.6.1 Internal proposals

"Theme-team" initiatives
Human Centered Robotics
Personalised Health and Wellbeing & Sports
Data Science & AI
Energy Optimisation

In 2019 the faculty decided to promote trans-disciplinary research within the faculty by awarding so called *"Theme-team" initiatives* (See Section 2.6). These projects are run by EEMCS teams on the four faculty themes: *Human Centered Robotics*, *Personalised Health and Wellbeing & Sports*, *Data Science & AI* and *Energy Optimisation*. Teams need to be composed of three junior staff members, one each from EE, Mathematics and Computer Science. The teams are responsible for developing the theme within the faculty. The grant provides the team members with three PhD students, embedded in the three disciplines and to be supervised by the three team members in cooperation. This instrument allows for agile reaction to new opportunities, while firmly anchoring the activities in the disciplines by the formation of teams.
For the three years from 2021 to 2023, the three EEMCS discipline will receive funding (0.6 M€ cumulative) from the faculty to support strategic activities to strengthen the discipline research port folio. The EE discipline has decided to use this funding to establish a systems integration lab for research and education in the discipline.

2.6.2 EE in Society

The field of electrical engineering forms a fast evolving and developing discipline. Worldwide it has a strong industrial base representing hundreds of billions of dollars in terms of sales, labour and investments. The latter can be on such extreme levels that academic players, like the EE discipline at the UT cannot even come close. However, at the UT, we pride ourselves on the facilities we have; the various labs are well equipped for their respective purposes with clear examples e.g. the Nanolab and the Robotics lab. More importantly, we feel that our lab-settings and open scientific culture allow us to foster multi- and trans-disciplinary research and provide the academic freedom to develop methods of design, analysis and fabrication that are of high interest to our (multi-billion) industrial partners. In the same vein we can facilitate pre-competitive research as well as address societally relevant research that does not have an industrial embedding (yet).

We describe what has been done in order to achieve the strategic aims. This description relates to choices, activities, intended partners or audiences, collaborations, etc.

3 Strategy

3.1 Introduction

The chairs in EE have a large autonomy to develop their own port-folio of research projects. However, for larger scale and longer term developments, e.g. for personnel changes (growth and reduction), the faculty forms the framework of reference for decision making. Following the developments over the last few years the 3 disciplines in the faculty EEMCS have been given increased freedom to profile their respective disciplines.

3.2 Strategy over the previous period

3.2.1 Financing of the research

In the full-term 2011–2016 self-study report we wrote under 'Research Vision': "We want to be successful in national funding schemes, as well as in the European Horizon 2020 programme and its successors". Looking at the financial overviews (QAR 2019) we find that we have been able to maintain a research funding of about 41% (9.3 M€) in 2nd and 3rd money streams relative to total income (22.5 M€). Of this total research project budget 3.1 M€ comes from EU projects, 2.3 M€ from contract research and 3.8 M€ from 2nd money-stream funding. At the same time we conclude that the total research project funding (9.3 M€) has increased relative to the amount of 2016 (7.7 M€) by 20%. Aiming for a growth of 30% in 2021 relative to 2016 we seem to be on target. Hence, we may conclude that our intent to be successful in EU and national funding has worked out well. Furthermore, it is comforting to see that the ratio of 1st money stream to total funding has remained at about 60%, suggesting a stable financial foundation for our activities.

3.2.2 Sectorplans

Sectorbeeld

In the Dutch 'regeerakkoord 2017' a significant investment was foreseen in science and research, including 60M€ for 'beta and techniek'. For this purpose, first a '*sectorbeeld*' [14] was written, describing the field, its challenges and ambitions. Based on numerical indicators like status-quo and required future student outflux, the financial means were divided over the disciplines at each university. The goal of the Sector plan was to strengthen the research in the core of the discipline. Because these plans have impact on our strategy for the next years, further details are given in Chapter 6.

3.2.3 New and discontinued groups

Radio Systems (RS)

Power Electronics (PE)

Integrated Devices and Systems (IDS)

In the previous report we expressed our intent to "Discontinue the TE (Telecommunications Engineering) group and establish a new *Radio Systems (RS)* group." Meanwhile this process has been concluded. In addition to the Radio Systems group, due to the impulse of the Sector Plan funding we were also able to establish the *Power Electronics (PE)* group where part of the previous TE research has found a good place as well. Likewise we merged the Micro Sensors and Systems (MSS) and Semiconductor (SC) groups into a favourably-sized group; the *Integrated Devices and Systems (IDS)* group. For the Biometric Pattern Recognition (BPR) group a comparably motivated merge with the *Data Science* group has been realised.

Data Science

3.2.4 Student numbers

In the previous full term report we noted: "We would like to have 120 first year's Bachelor EE students and 65 Master EE influx before 2021." In 2019 we were able to realise a BSc influx of 99 + 18 premasters whereas the MSc influx was 89, both reasonably in line with our intentions and obligations to society. The 2020 pandemic has reduced student mobility severely and reduced student influx somewhat in 2020, but may be more disruptive for 2021, especially for the MSc programme where the influx is rather international. Research and education are strongly interwoven, not only by the bachelor and master assignments and student embedding in research groups, but also by the dynamic and multidisciplinary atmosphere that is created by several multidisciplinary bachelor and master studies at the UT. The bachelor study Creative Technology creates an acute awareness for the impact of technological solutions, and always aims to contribute to society. This awareness contributes to the open mindset of the investigators at Twente, even more as it is supported by the infrastructure of the Design Lab. Similar contributions are given by the master study Technical Medicine and the Techmed Centre, and the bachelor study Advanced Technology. The new master robotics and the creation of the robotics centre aim to contribute in a similar way in the future to the robotics and artificial intelligence theme.

We present and explain our KPIs (Key Performance Indices) for products, use and marks of recognition for both quality domains (research quality and relevance to society). Case studies are omitted in the Midterm Review.

4 Evidence

4.1 Key Performance Indicators

The key performance indicators (KPIs) have been chosen to reflect the values of the EE discipline. We aim for outstanding research in an open academic culture, collaborative, oriented on and inspired by society. In this fashion we remain relevant to society and vice verse. We strive our science to be open, though respecting the interests of societal partners like companies. Table 4.1 lists the resulting 6 KPIs

Table 4.1
Key Performance Indices

Assessment Dimensions	Quality domains: Research quality	Quality domains: Relevance to society
Demonstrable products	**1. Research products for peers** a. Publications: Articles in a selected set of main journals and conferences, Dissertations	**4. Research products for societal target groups** a. Enough well-educated Masters and PhDs b. Spin-off and start-up companies
Demonstrable use of products	**2. Use of research products by peers** a. Keynotes	**5. Use of research products by societal groups** a. Technical products (designs, software, methods, and patents)
Demonstrable marks of recognition	**3. Marks of recognition from peers** a. Major awards and grants (ERC, Veni, Vidi, Vici, large research grants b. Senior positions in research-related organisations and leadership of (inter)national research projects)	**6. Marks of recognition by societal groups/companies** a. Long-term Research funding from industry

4.2 Evidence in terms of the KPIs

4.2.1 Research products for peers (Publications and Dissertations)

The result of our research find their way to our peers in publications in high-quality journals and a number of selected conferences. Figure 5.1 and Table 5.1 show our output in the last six years.

The research output in the form of peer-reviewed journal articles and conference contributions can be seen to have declined in the last three years, while the number of PhD theses has remained approximately constant at 30 per year. The precise cause of this decline is presently unknown. Also dissertations, the result of PhD projects, should be mentioned here. After a dip, due the reorganisation, the number of PhD theses is almost at the level of 2014 again (Table 5.1).

4.2.2 Use of research products by peers

Table 4.2 Keynotes

group	year	keynote
DACS	2016	Aiko Pras: Keynote presentation at IEEE/IFIP Network Operations and Management Symposium
		Geert Heijenk: Invited presentation at IEEE Vehicular Technology Society Workshop on Wireless Vehicular Communications, Halmstad
	2018	Aiko Pras: Keynote ACM SIGCOMM 2018 Workshop on Traffic Measurements for Cybersecurity
	2019	Geert Heijenk: Keynote presentation at the 17th International Conference on Wired/Wireless Internet Communications (IFIP WWIC)
		Geert Heijenk: Keynote presentation at IEEE Wireless Days, Manchester

4.2.3 Marks of recognition from peers

Tables 4.3a and 4.3b summarise the major awards and grants of the last three years.

Table 4.3a Marks of recognition from peers (1) (continued in Table 4.3b)

group	year	project	budget
AMBER	2018	TURBO grant	80 k€
		Member of the board of directors of the Chemical & Biological Microsystems Society	
	2019	PiHC	70 k€
		TKI-LSH HOOCS	430 k€
		ZonMW Microplatics & Health	150 k€
	2020	TKI-LSH QoroNano	231 k€
		UT-WWU	80 k€
BIOS		EC Open Top	150 k€
		Keygene	450 k€
		Perspectief Smart OOC	2.2 M€ total, 500 k€ UT
	2017	PI en co-PI zwaartekracht proposal NOCI	19.2 M€ total, UT 3.5 M€
	2018	PI, Grant from 'stichting de Weijerhorst'	1.8 M€ (+0.46 M€ TKI, cancer research)
		MCEC 2nd phase: 12 M€ , 2.2 M€ UT	
	2019	PI H2020 Electromed	550 k€
	2020	PI EU POC Digipredict	4 M€ total, UT 800 k€
		Albert van den Berg: Chairman Nano4Society (before: NanoNextNL)	
		Albert van den Berg: co-founder EUROOCS (EuropeanOrgan on Chip Society)	
		Albert van den Berg, Chairman of Section Applied Sciences of the KNAW	
		Albert van den Berg member of the KHMW	
		Albert van den Berg and Jan Eijkel: member of Max Planck Center Twente	
		Albert van den Berg and Jan Eijkel: visiting prof at SCNU and NPU (China)	
		Maxima Medisch Centrum/UT/Tobias Sybesma foundation (cancer research)	collaboration >5 temporary academic staff
		Weijerhorst: Amsterdam UMC en UT	collaboration >5 temporary academic staff
BPR	2018	State of the art of Morphing Detection	202 k€ out of 1.2 M€
	2020	MC-ITN PriMa	14 aio's UT coordinator, 3.83 M€
	2020	EU image Manipulation Attack Resolving Solutions	450 k€ out of 6,5 M€
BSS	2017	EU (coordination) - COUCH	545 k€
		IMPULS Mr Niersleerstoel	110 k€
		De Diameter	50 k€
		Specialistische zorg thuis	40 k€
	2018	WO-ZonMW - E-manager	340 k€
		U-EFRO - PROMPT	400k €
		NWO-ZonMW - Smart Sports Exerc.	147 k€
		Geriatrie Heupfractuur	225 k€
	2019	NWO-Commit2Data (coordination) - EDIC	543 k€
		TKI - Personalized AP	412 k€
		U - Phara-on	490 k€
		Topfit Citizenlab	249 k€
		Vigour	125 k€
BSS	2020	Witteveen: NWO-ZonMW Veni	250 k€
		Jan Buitenweg: TKI project Nocitune	580 k€
		WO - Perfect Fit	335 k€
		NWO-TTW - PARTNR	650 k€
		NWO-ZonMW - ArmCoach4Stroke	114 k€
		NWO-cross-over - INTENSE	287 k€
		FRO - INSTANT	258 k€

Table 4.3b Marks of recognition from peers (2) (Table 4.3a continued)

group	year	project	budget
CAES	2017	STW: ULPT: Ultra-low power transponders for vulnerable road side users	434 k€
		STW: APSN-CAES Autonomous parking sensor networks	214 k€
		STW: ARM Autonomous roadside monitoring	426 k€
		STW: UT 5G Upconverting transmitters for 5g power efficiency in digital and analogue	286 k€
		Penta Project Hades	total: 1.3 M€, 613 k€UT)
	2018	NWO: EDLP Efficient deep learning platforms	218 k€
	2019	Baver Ozceylan, Boudewijn R. Haverkort, Maurits de Graaf, Marco E. T. Gerards The Harvey Rosten Award for Excellence (http://rostenaward.com/)	
		Energy projects, collaboration with MOR and/or BMS:	
	2019	- OP-OOST EFRO "Vliegwieltechnologie voor energieopslag in microgrids"	2.6 M€total (250 k€ UT)
		- NWO Cybersecurity Project ISOLATE	250 k€
	2020	- H2020 Project SERENE	805 k€
		- H2020 Project SUSTENANCE	700 k€
		- RVO TKI SLIMPARK	130 k€
		- RVO TKI FAIRPLAY	1.2 M€ total (220 k€ UT)
		- RVO DEI+ Buurtbatterij in de Weverij	452 k€
DACS	2017	Hans van den Berg: Arne Jensen Lifetime Achievement Award, ITC	
	2020	Roland van Rijswijk-Deij: KHMW Kees Schouwhamer Immink Prize	
	2020	Roland van Rijswijk-Deij: IEEE TCI Rising Star Award	
		Concordia (EU Horizon 2020)	total budget 16 M€, UT 500 k€
		Intersect (NWO NWA ORC)	total budget 8 M€, UT 1 M€
		Aiko Pras: Research Coordinator Concordia Cybersecurity Competence Network	
		Geert Heijenk: steering committee member IEEE Vehicular Networking Conference	
ICD	2017	STW: APSN-ICD Autonomous parking sensor networks	214 k€
		STW: UT 5G Upconverting transmitters for 5g power efficiency in digital and analogue	325 k€
		Agentschap NL: Varsities 1	313 k€
		Agentschap NL: Varsities 2	313 k€
	2019	EU Horizon 2020: HIGH RISK NO GAIN	2.475 M€
		LOW NOISE BALLIN	74 k€
ICD / IDS	2018	3 TU project Plantenna	960 k€
IDS	2017	Interreg: XTC ID Extreme temperatuur chip radio frequentie identificatie technologie	322 k€
		Agentschap NL: MIRACLE Material independent rear passivating contact solar cell	95 k€
	2018	NWO: EX3VAGAND Energy efficient electron GaN devices	270 k€
		Agentschap NL: HAVALDAR High added value atomic layer deposition apparatus and recipes	697 k€
		EFRO: MAP Microneedle artificial pancreas system for postprandial glucose control	185 k€
	2019	NWO: Synoptic optics	372 k€
NE	2017	NWS Startimpuls	400 k€
	2018	FLAG-ERA	800 k€
	2019	NWO Vrij Programma	3 M€ , UT 400 k€
		FETOPEN coordinator	3.1 M€ , UT 900 k€
	2020	ENW Groot	2.2 MEUR, UT 1.2 M€
		FET FLAG	14.5 M€ , UT 400 k€
PE	2018	Frank Leferink:Vice-Chair EMC Europe conferences	
		Frank Leferink:Tech. Program Committee Chair 2021 APEMC conference	
		Frank Leferink:Tech. Program Committee Chair 2022 IEEE EMC conference	
	2019	Frank Leferink: IEEE fellow	
		Frank Leferink: re-appointed Honorary professor EMC, University of Nottingham, Nottingham, UK	
	2020	Frank Leferink:appointed as Ambassador Chair KU Leuven, Belgium	
	2019	Shenzhen-TwentePower Electronics	3 M€
PE (EMC)	2017	EMPIR (H2020) MeterEMI	313.6 k€
	2018	MSCA (H2020) SCENT , UT coordinator	1.024 M€ of total € 2.258 M€
		MSCA (H2020) PETER 599 M€	
	2019	MSCA (H2020) ETOPIA, UT coordinator	795 k€ of total 3 M€
	2020	H2020 EASIER	315 M€
		NWO ANRGI, UT coordinator	690 k€
		MSCA(H2020) ETERNITY € 315 k€	
		MSCA(H2020) ETUT, UT coordinator	1.235 M€ total 3.162 M€
		MSCA belongs with ERC to Pillar1: Excellence Science, of the EU. applications: 7% success rate	
RAM	2017	Softpro EU	380 k€
	2018	ERC Advanced grant Portwings	(2.8 M€)
		ReElection of Stramigioli as Vice President Research euRobotics [22]	
		Wearable Robotics	236 k€
		4TU Soft Robotics	277 k€
	2019	EU DIH-HERO	(16 M€, coordinator), UT 1.7 M€
		EU WEAFING: Wearable electroactive fabrics	UT: 294 k€
		EU RIMA, Robotics for infrastructure and maintenance	UT 346 k€
		AerialCore	
		EU Robot software architectures using model driven design	UT 125 k€
		FlexCraft	
		Stefano Stramigioli: member KHMW	
	2020	Stramigioli: Incoming Vice President IEEE Robotics and Automation MAB	
		Pioneers in Healthcare	59 k€

4.2.4 Research products for societal target groups

During the years EE has helped many Spin-offs and Start-ups to start their business helped by theTOP arrangement. At least one of them (Demcon) has grown to a company with more than 750 employees. Table 4.4 gives a few enterprises started in recent years.

group	year	company
BIOS		Semen refinement
		BVQurin
NE	2020	Semirtec
NE+AMBER	2019	ECsens
RAM	2020	MachNed medical Robotics
		Multimotor

Table 4.4
Spin-offs and Start-up companies

4.2.5 Use of research products by societalgroups

Table 4.5 Technical products: plus projects with industry

group		Technical products: plus projects with industry	
BSS		Bert-Jan van Beijnum (Ambition project): BSS proposed and validated algorithms for assessing spatio-temporal and balance parameters during gait using 3 IMU's: A demonstrator product has been developed by 2M Engineering based on these algorithms	
CAES	2017	HADES Hierarchy aware and secure embedded test infrastructure for dependability and performance enhancement of integrated systems	
DACS	-	OpenINTEL DNS Measurement Platform (measures over 50% of entire Internet DNS name space), and measurement data	
	-	DDoS Clearing House	
	-	(models of) protocols for vehicular networking	
	-	enhancements to Secure DNS	
	-	models/algorithms for mobile network management	
ICD	2019	Arbitrary digital clock	400 k€
		ULP building blocks	400 k€
		5G RF Ttransceiver integration	400 k€
	2017	DOWNCONVERTER 2: Low power rf downconverter receiver frontend 2	300 k€
		ICARUS Increased collection of energy by advanced solar harvesters on roof mounted solar panels	€ 65 k€
IDS	2019	Postmortem analysis of solar cells	120 k€
		Gas monitor module for respiratory devices	439 k€
	2018	NEXTGENSCT Next generation surface channel technology	615 k€

4.2.6 Marks of recognition by societal groups/companies

group		Long-term research funding
BSS		In cash contributions by Inreda (67.7 k€:
	-	TKI-Connecting Industries Personalized AP project (granted in 2019):
		Part-time staff positions by societal organisations:
	-	0.2 FTE prof.dr. Jaap Buurke: financed by Roessingh Research and Development
	-	0.2 fTE prof.dr. Goos Laverman: financed by ZGT
	-	0.2 FTE pr. Han Hegeman: financed by ZGT
DACS		part-time staff positions (0.2 fte) paid by other organisations
	-	TNO
	-	SIDN Labs
	-	NCSC
	-	Nedap
	-	Northwave
IDS		0.2 fte (prof. Joost Lötters) paid by Bronkhorst
RAM		i-Botics programme with TNO

Table 4.6
Long-term research funding

Here we describe the results we achieved in the past six years. The results relate to research quality as well as societal relevance and include a reflection on the teaching-research nexus, where applicable.
The narrative can be substantiated by indicators and by referring to the case studies.

5 Accomplishments during the past three years – research quality and societal relevance

5.1 Research quality

Here we describe our research quality in terms of of Publications, as well as the relevance for society in terms of BSc and MSc graduates and startup companies.

5.1.1 Publications

Figure 5.1
Publications

(based on data from PURE 2020.
See Table 5.1)

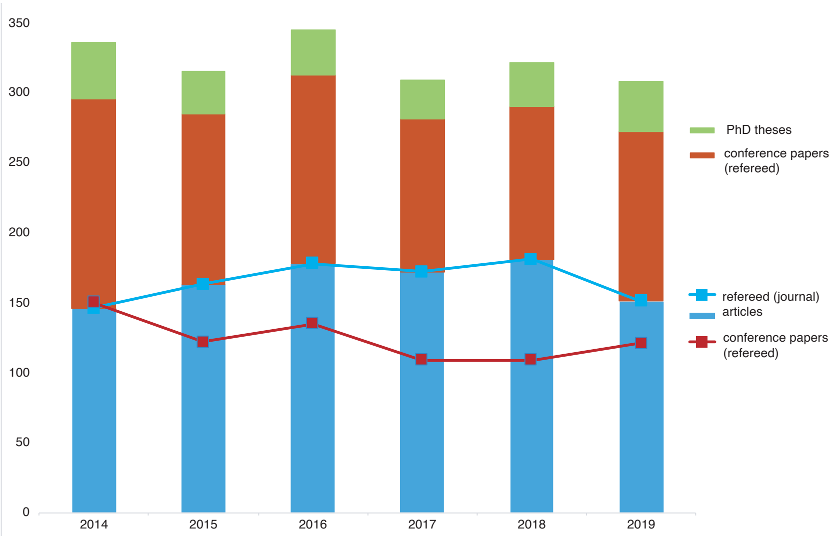


Table 5.1
Publications

	2014	2015	2016	2017	2018	2019
refereed (journal) articles	146	163	178	172	181	151
non-refereed articles	6	4	3	0	3	3
Book chapters	11	15	6	9	6	6
Books	1	1	1	1	1	2
PhD theses	40	30	32	28	32	36
(Refereed) conference papers	150	122	135	109	109	121
Non-refereed conference papers	25	21	19	8	8	7
Professional publications	4	3	3	7	5	4
Publications aimed at the general public	1	1	1	0	0	1
Other research output	10	7	15	6	37	49
Patents	6	4	6	3	8	4
Total publications	400	371	399	343	390	384

5.2 Teaching-research nexus

5.2.1 Academically qualified engineers

The 'production' of highly-qualified engineers is one of our main duties. Figure 5.2 and 5.3 show that after a few years with a low student intake and MSc output, these numbers have recently strongly improved.

Figure 5.2
MSc graduates Electrical Engineering

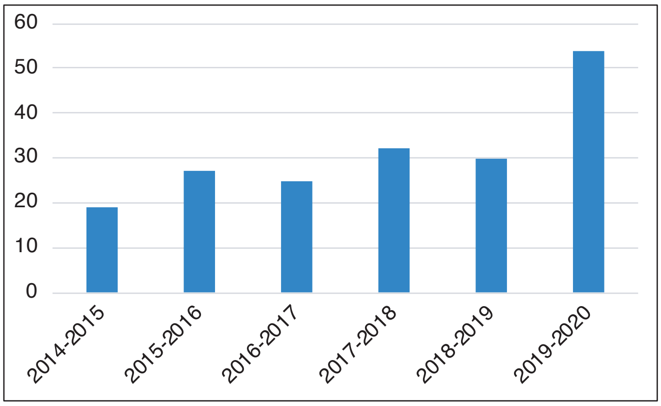
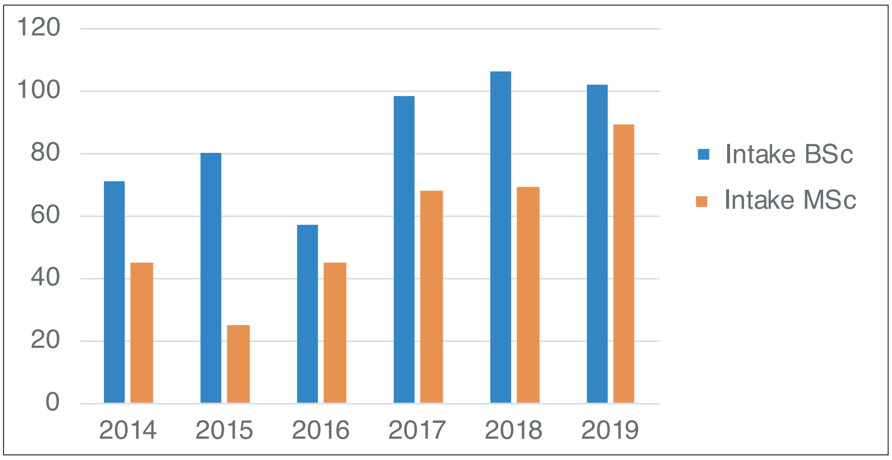


Figure 5.3
Intake BSc and MSc students Electrical Engineering



5.3 Start-ups

From 1993 onwards, around 20 companies started up on the basis of research performed at the Electrical Engineering department, many by the students themselves. Many kept their main base in the Kennispark Twente adjacent to the UT Campus, where some have strongly grown since they were established. Technology company Demcon, started in 1993, has a present size of 750 employees. Technology transfer company 3T now has a size of 100 employees, and Micronit Microfluidics (1999), a spin-off of the micromachining groups of EE, also 100 employees. Several other successful companies still present at the UT campus or the Kennispark have been acquired by foreign companies, such as Xsens (140 employees, 2014 to Fairchild Semiconductor), AXIOM IC (20 employees, to Teledyne-Dalsa in 2013) and the photonics and MEMS company Lionix (40 employees, for 75% acquired by Magic Micro in 2018). Of special note is the company Athom as it was started by students from Creative Technology. It builds domotics solutions and presently has a size of 18 employees.

We reflect on the strategy needed for the future. We present a SWOT analysis, in which we analyse strengths, weaknesses, opportunities and threats. The strengths and weaknesses relate to the properties as well as the characteristics of the research unit. The SWOT analysis forms the basis of the strategic plans for the three years to come.

6 Strategy for the next three years

6.1 Sectorplans

The Field of Electrical Engineering has a long history and has enabled many changes in society. During the past three decades the research in EE has grown, especially at the 'borders' of the field, making these applications possible. This has had immense positive impact on society, however the pure discipline focused research in the core of the discipline has been shifted to lower activity due to this. In the Dutch 'regeerakkoord 2017' a significant investment was foreseen in science and research, including 60M€ for 'beta and techniek'. For this purpose, first a 'sectorbeeld' [14] was written, describing the field, its challenges and ambitions. Based on numerical indicators like status-quo and required future student outflux, the financial means were divided over the disciplines at each university. The goal of the Sector plan was to strengthen the research in the core of the discipline. The investment focus areas for the Dutch EE are summarized in the table below [14].

Table 6.1 Investment focus areas

Kern-discipline	Focusgebied	Gerelateerde sterktes
Communicatie en Signaalbewerking	Convergentie radio en fotonica	Fotonica, draadloze en optische communicatie, More than Moore-technologie
	Elektromagnetische signaal-opwekking en –ontvangst en signaalbewerking	Draadloze communicatie, signaalbewerking, More than Moore technologie, analoge elektronica
Elektronische componenten, circuits en systemen	Ontwerpmethodieken voor elektronica en systemen	Analoge elektronica, More than Moore-technologie, digitale elektronica en systemen
	More than Moore-technologieën	Analoge elektronica, More than Moore-technologie
Elektrische Energieconversie	Gedistribueerde elektrische energievoorziening	Energietechniek
	Elektromechanische systemen en vermogenselektronica	Actuatoren, regelsystemen

With clear goals in mind, the disciplines of Mechanical Engineering, Electrical Engineering and Civil Engineering at the University of Twente jointly wrote their 'Profileringsplan UT Techniek' [15] in which was described how these investments should be implemented. This included a national alignment for these disciplines: For EE the alignment was made with Delft, Eindhoven and Wageningen.
Within the discipline EE at UT, several strategic sessions were organized to make our plans. Our target was to define 6 new positions for permanent scientific staff. To create competition however, the universities were challenged to over-ask, resulting in a request for 9 positions with M€ 1.430.000 funding. After the process 6 positions received funding through the 'sectorplannen' and the remaining 3 were funded by the university board (CvB).
Thanks to our research institutes, EE in Twente is strong in the application areas covered by these institutes. However, the core field of Power Electronics was completely missing while computing hardware/processing as well and radio systems could be enforced. In order to strengthen EE in these core fields a new group 'Power Electronics' was formed, strengthened by our existing EMC activities. Also, a new group 'Radio Systems' was formed, created partly from the discontinued group 'Telecom

Engineering' and a part of 'CAES'. The 9 new positions, arranged by the 3 core disciplines as in the table above are given below

- Radio Systems / Phased Array front ends
- Radio Systems / Phased Array front ends
- Signal Processing / Image Processing

- Moore than More Technologies / Vertical Integration
- Electronic System Design / Advance Digital Hardware
- Electronic System Design / Neuromorphic Computing and Artificial Intelligence

- Power Electronics / General
- Power Electronics / EMC fundamentals
- Power Electronics / Power Conversion Circuits and Control

In the mean time, 7 people have been appointed (January 2021), who all have been given starting packages.

6.2 New strategic research fields

New strategic research fields

Strategic research fields that currently are in (further) development and that relate to EE are Robotics, Neuromorphic computing, Artificial intelligence, and (E-)health. Additionally we currently look into the field of Photonics in the context of an EE, systems-approach. For example, from a technological viewpoint we like to concentrate on vertical integration of photonics and electronics, with a firm industrial embedding to safeguard long-term application perspectives.

6.2.1 Robotics Centre

Twente Robotics Center

In the field of robotics we aspire to form a new *Twente Robotics Center*. Evidently, robotics is a multidisciplinary activity in which many research fields merge: mechanics, electronics, embedded systems, (human) physiology, machine learning, artificial intelligence, imaging, advanced fabrication (e.g. additive manufacturing), human media interaction, etc. It is a widely shared expectation that: "Robotics and AI will shape the way we work, live, produce and operate in society". Politics, society and industry are recognising this and as a leader in science, education and entrepreneurship, the University of Twente will take the proper actions to anticipate this trend and provide what society expects and needs. In the new Robotic center the goal is to focus on Robotics for Citizens and to show how Robotics can evolve for the Citizens of the future.

Twente Robotics Institute

At the UT research is done on most of robotics related subjects, however, this research is spread over 2 faculties and 3 disciplines, physically and for the outside world also perceptionally, separated. To improve cross-fertilisation, be a recognisable player, to be a one stop interface to the 'external world', and attractive to industry and excellent researchers we will found a new *Twente Robotics Institute*. To this end the participating chairs from the EEMCS faculty (Robotics and Mechatronics, and the Human Media Interaction chairs) and the Engineering Technology faculty (Biomechanical Engineering and Precision Engineering groups) develop an integral strategy for housing, research, education, and robotics innovation.

The new center will be at the heart of an ecosystem, encompassing a vision which connects education to research, to valorisation in a unique attractive space on campus for researchers, students (Bsc,Msc,Phd), entrepreneurs and other stakeholders to catalyse each-others' strengths. As part of the integral strategy we are currently developing a new MSc programme Robotics addressing the needs, of amongst others, Medical, Inspection & Maintenance, Industrial (Agile Manufacturing & High-Tech Systems) and Agro-Food sector robotics.

6.3 Financial autonomy

Financial autonomy

A healthy financial policy with room for investments in new promising developments, sufficient personnel for all departmental tasks and fitting state of the art infrastructure forms the backbone for successful operation. The EE groups have recently adapted a new financial governance model. This model does not touch the normative part of the faculty allotment, but is focused on the research part in order to allow for an increased dynamic in terms of starting and finishing chairs. Using a weighted sum of 2nd, 3rd and EU money flows, promotion premiums and education rewards over a 5 year period the non-normative part of the EE income is distributed over the chairs. Some simple rules for allotment of starting members and groups are in place to enable more agile developments, focusing on research rather than financial commitment.

6.4 Personnel

Retirement wave

Attracting new staff members is a top priority. A sizable part of our staff will retire in the coming 5-10 years. Also the technical support will suffer from this '*retirement wave*'. The junior sector plan positions and a number of tenure trackers in a number of cases can provide possible successors for the scientific staff, and attracting high-quality technicians is hard in the current market. Offering these technicians better growth possibilities in the organisation than the present ones, will be a helpful means for attracting them in the first place, but also for keeping them in the organisation. Having some period of overlap with the leaving staff member is furthermore desirable.

6.4.1 Diversity

Prioritize female applications

Diversity and especially the gender balance needs constant attention. Traditionally in EE the number of female students is very low and as a result it is difficult to find qualified female staff. This is especially true for Dutch people. Finding new staff internationally contributes to the intercultural diversity. The goal of the faculty of EEMCS for 2025 is to employ 20% female full professors 20% Associate and 35% Assistant professors. At present these numbers are 12% full professors 13% Associate and 30% Assistant professors. To achieve this goal it will be necessary to fill 50% of all vacant positions with female staff. Currently the faculty EEMCS is looking into possibilities to *prioritize female applications*.

6.5 Conclusion

Energy transition

Battery technology

Robotics

We expect that in the coming years EE will be more important than ever. The *energy transition* is all about replacing fossil fuels by sustainable electrical energy, often leading to increased dynamics of supply and demand and requiring advanced solutions to guarantee proper provisioning. It also asks for a reduction of the power consumption of our electronic devices and machines (like e.g. has happened in LED lighting, portable and computing devices, electric car engines, domotic solutions for interior climate). Also in the field of energy storage, especially in *battery technology*, EE has an important role to play with respect to control and efficiency of the de/charging processes. The societal tendency to be online wherever and whenever we want and to connect all sorts of equipment (Internet of Things) is driving the impact of these technological developments even more. Electronic devices still continue to grow in numbers and capabilities. Opto-electronics will enhance electronic devices. Automation in the form of e.g. *robotics*; self driving cars and autonomous flying drones will become mature. In agriculture and livestock farming GPS, sensors, computer-systems are increasingly used to improve efficiency, animal welfare, quality control, increase production volume. Medical technology is a growing field; advanced and pervasive sensing of vital indicators, diagnostics, organ-on-chip, tele-operating, e-health all are based on (enabling) technology from the EE domain.

In short, society is counting on the EE discipline and its engineers to play their important part in pressing societal problems and possible solutions. The demand for EE engineers seems to increase and there is more work to be done than ever. At the UT we take on a set of these challenges consistent with the manpower, infrastructure and expertises that we have and expend where possible. The future for the EE discipline in general as well as for the EE department at the UT is bright!

6.6 SWOT-analysis

Table 6.2 SWOT analysis, composed during a brainstorm session of the EE profs

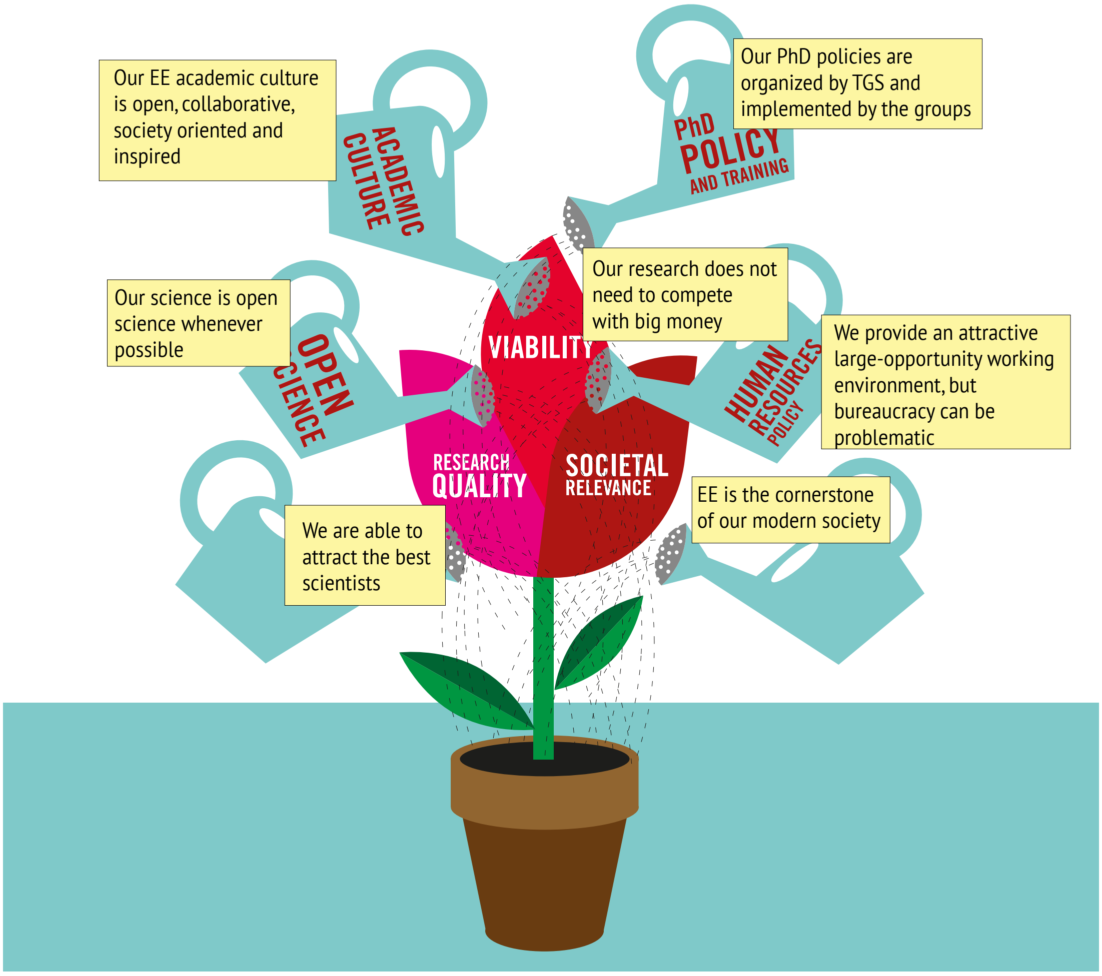
Internal organisation	**Strengths**	**Weaknesses**
	• Internationally renowned staff • Retirement of senior staff offers chance to rejuvenate, optimize research themes, bridge groups • Our strong teams support young talent • Strong ongoing cooperation within EE, faculty, institutes, university • Strong EE core and strong cross-disciplinary applications supported by institutes • High vertical mobility of scientific staff • Staff has excellent connections with high-tech industry • Research of all groups relates excellently to societal challenges • Societal mindset and intensive collaboration with societal stake holders	• Retirement of senior staff decreases coaching power for junior staff • Insufficient time spent to get to know each other's research • Too much bureaucracy • Complex management structure (departments, clusters, disciplines, faculties, institutes, zwaartepunten) • Disjunct activities in embedded AI; limited visibility • Limited vertical and horizontal mobility supporting staff • Quite some PhDs take > 4 years; less financial support for grant PhDs • Ethics and data management need to be more widely implemented and grow into the DNA of the organization • Very few female students; • Little female interest for open positions • Academic qualities of MSc and BSc students EE declining
External context	**Opportunities**	**Threats**
	• Economic dip after corona provides opportunity to attract high-quality staff • Enabling MKBs in Twente region • Talent scouting • Lot of potential for technical embedded AI/robotics, IOT, energy transition • Attract top talent by offering clear grow paths for junior faculty • Create a portal to share our results; become 'an example for all'	• Economic dip after corona worsens financial situation • Maturing Si industry is leaving NL

The self-evaluation document is complemented with a one-page summary.

7 Summary

The front page of the SEP protocol 2021-2027 [2] shows the items, which should be addressed in this report. Figure 7.1 summarises how we see this for EE, by adding some yellow notes. The disciplinary council of electrical engineering decided on these statements that each concern central elements for the SEP protocol.

Figure 7.1
Viability, Research Quality and Societal Relevance



EE is the cornerstone of our modern society

We all fully agree with this statement, as will also be clear from the entirety of this report.

Our EE academic culture is open, collaborative, society oriented and inspired

We agree with this statement. We felt 'open' was the keyword: we are open to society and we give back to society. 'Open' is our culture. As point of critique was mentioned, that the UT higher management was not always experienced as open.

"Our science is open science whenever possible

We perform our science for the good of society and for the good of the whole, which must be reflected in open publication of the results. Additionally, to optimally answer to the needs of companies and finally implementation of our research results in society, a temporary protection can be necessary (patents, embargo's).

Our PhD policies are organized by TGS and implemented by the groups

PhDs are crucial for our research. We need them and they form the heart of our science. Intensive supervision is therefore of central importance. The organization of TGS provides a good framework for the PhD supervision. Talent development and academic development occur in the groups and have our full attention. We need to continuously reflect on the core values we try to instill.

Our research does not need to compete with big money

Our research has a different character from the research typically performed in large companies. We can take unique steps in our research, and think of creative new concepts 'out of the box'. We can also perform pre-competitive research. We are equipped to analyse and understand, to answer the 'why' questions. The Nanolab infrastructure is unique and allows us to technically explore new materials. In this manner we can cooperate with big money and large companies.

We are able to attract the best scientists

Our strong points are our infrastructure (Nanolab), our innovative education (Create, technical medicine), as well as our high-quality researchers and strong teams (talent attracts talent). We are situated at some distance from the Randstad, but are surrounded by much SMEs (Kennispark). Sometimes we will be like Ajax: educating the top talents of the future.

We provide an attractive large-opportunity working environment, but bureaucracy can be problematic

We experience the bureaucracy, especially the often dysfunctional software systems, as an increasing problem. It distracts from our primary task and causes unnecessary stress.

Electrical Engineering is a thriving research area. The societal importance of the EE discipline and its viability, in general and particularly at the University of Twente, are beyond any doubt. Looking back to the past decade of EE at the UT, we observe that the discipline has strongly recovered from the 2013 reorganization both personnel-wise and financially. EE boasts strong research teams with internationally renowned staff, that have excellent connections to high-tech industry. The development of the discipline has recently been spurred by the strong investments in the three core disciplines of EE (the white center in Figure 1 at page iv) by the sector plan. These investments are expected to especially enable further developments in energy and AI. In the future we see many chances in the area of robotics, health, energy and artificial intelligence, with strong ongoing initiatives in the applied areas of robotics, embedded AI, neuromorphic computing, organ-on-a-chip and E-health (the blue outer circle in Figure 1). Several issues will need attention in the coming years: the retirement of several senior staff, which offers both an opportunity and a challenge; the attraction of more female students and staff; relieving the administrative burden for the research staff and generally decreasing the working pressure to create more space for creativity. The excellent infrastructure of the UT campus and the societal and open mindset in the discipline and the UT in general will undoubtedly help addressing these issues.

The appendices include tables with figures on composition, funding and the status report of the Sector plan

8 Appendices

A1 Output indicators (KPIs)

The KPI's are listed in Table A1.a.

Table A1.a
Key Performance Indices

Assessment Dimensions	Quality domains: Research quality	Quality domains: Relevance to society
Demonstrable products	**1. Research products for peers** a. Publications: Articles in a selected set of main journals and conferences, Dissertations	**4. Research products for societal target groups** a. Enough well-educated Masters and PhDs b. Spin-off and start-up companies
Demonstrable use of products	**2. Use of research products by peers** a. Keynotes	**5. Use of research products by societal groups** a. Technical products (designs, software, methods, and patents)
Demonstrable marks of recognition	**3. Marks of recognition from peers** a. Major awards and grants (ERC, Veni, Vidi, Vici, large research grants b. Senior positions in research-related organisations and leadership of (inter)national research projects)	**6. Marks of recognition by societal groups/companies** a. Long-term Research funding from industry

A2 Relevance of the research unit's work to society

See the listings in Chapter 4.

A3 Research

In Table A3.a the development of the research staff in the last six years is given.

Table A3.a
Research staff in FTEs

	2014	2015	2016	2017	2018	2019
Hgl	12,90	12,68	13,14	12,90	12,97	12,26
UHD	15,38	16,48	19,04	18,68	20,76	21,66
UD	11,08	11,48	10,84	12,94	12,15	11,80
AIO/OIO	108,08	102,79	102,89	99,73	100,42	116,47
AIO contr	11,26	13,33	17,24	17,04	25,90	26,61
MOZ	37,72	38,02	33,31	31,36	27,93	39,81
Total research staff	196,42	194,77	196,46	192,64	200,13	228,61
Docent	1,77	1,39	1,62	2,06	3,54	3,88
Technicians	18,17	18,06	16,50	17,16	17,93	16,26
Secretaries	8,81	8,52	7,50	7,38	7,64	6,86
Other	1,55	1,87	2,81	4,39	2,99	3,10
Total staff	226,72	224,61	224,89	223,63	232,23	258,71

In recent years the faculty EEMCS used a rather strict system (EPRINTS) for counting publications. E.g. only publications with an ISBN number (or similar) are accepted by the system. Abstracts and posters are not counted. In 2017 a new system (PURE) has been introduced.

Table A3.b
Publications

	2014	2015	2016	2017	2018	2019
refereed (journal) articles	146	163	178	172	181	151
non-refereed articles	6	4	3	0	3	3
Book chapters	11	15	6	9	6	6
Books	1	1	1	1	1	2
PhD theses	40	30	32	28	32	36
(Refereed) conference papers	150	122	135	109	109	121
Non-refereed conference papers	25	21	19	8	8	7
Professional publications	4	3	3	7	5	4
Publications aimed at the general public	1	1	1	0	0	1
Other research output	10	7	15	6	37	49
Patents	6	4	6	3	8	4
Total publications	400	371	399	343	390	384

Figure A3.a

Publications

(based on the data of Table A3.b)

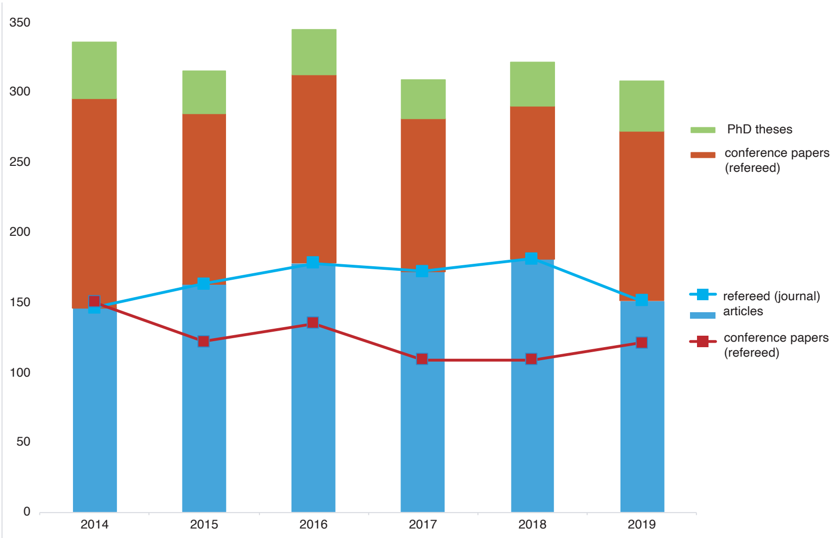


Table A3.c Funding [5]

	2014		2015		2016		2017		2018		2019	
Funding	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding [1]	7553	40%	7599	43%	8699	47%	9358	52%	10529	55%	10385	48%
Research grants [2]	4216	23%	3596	20%	4481	24%	4480	25%	4563	24%	4667	22%
Contract research [3]	6899	37%	6427	36%	5310	29%	4034	23%	4150	22%	6515	30%
Total funding	18668	100%	17622	100%	18490	100%	17872	100%	19242	100%	21567	100%
Expenditure	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Personal costs	14123	76%	13822	78%	14463	78%	14223	80%	15164	79%	17471	81%
Other costs	4545	24%	3800	22%	4027	22%	3649	20%	4078	21%	4096	19%
Total expenditure	18668	100%	17622	100%	18490	100%	17872	100%	19242	100%	21567	100%

Note 1: Direct funding (basic funding / netto lump-sum budget for research and education) excluding housing and Faculty overhead)
Note 2: Research grants obtained in national scientific competition (e.g. grants from NWO and the Royal Academy)
Note 3: Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, European organisations and charitable organisations
Note 4: Funds that do not fit into the other categories
Note 5: To enable comparison of the financing of the 3 TUs housing is left out of the first money flow and the costs. All funding is for paying staff, investments and consumables.

A4 SWOT analysis and Benchmark

See Table 6.2 at page 22.

Table A3.d PhD candidates

	Enrollment			Success rates											
Starting	Enrollment (male/female)		Total (M+F)	Graduated in year 4 or earlier		Graduated in year 5 or earlier		Graduated in year 6 or earlier		Graduated in year 7 or earlier		Not yet finished		Discontinued	
	#M	#F	# Total	#	%	#	%	#	%	#	%	#	%	#	%
2010	31,85	14,75	46,6	4,25	9%	24,1	52%	32,1	69%	34,6	74%	4	9%	8	17%
2011	32,87	10,5	43,37	5,6	13%	25,17	58%	32,17	74%	32,17	74%	6,2	14%	5	12%
2012	33,5	11,25	44,75	4,25	9%	20,75	46%	25,75	58%	29,75	66%	3	7%	12	27%
2013	27,64	7,5	35,14	2	6%	17	48%	24,5	70%	25,92	74%	3	9%	6,22	18%
2014	25	6,5	31,5	4	13%	16	51%	21,5	68%	21,5	68%	7	22%	3	10%
2015	32	10	42	5	12%	21	50%	21	50%	21	50%	14	33%	7	17%
2016	28	10	38	3	8%	6	16%	6	16%	6	16%	27	71%	5	13%
2017	22	11	33	2	6%	2	6%	2	6%	2	6%	27	82%	4	12%
2018	33	18	51	3	6%	3	6%	3	6%	3	6%	42	82%	6	12%
Total	167,64	63	230,64	19	8%	65	28%	78	34%	79,42	34%	120	52%	31,22	14%

A5 List of the five most important societal publications

The list of the five most important societal publications will be skipped for this mid-term review.

Index

References

[1] Accompanying web site
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