Strengthening the foundations of TU/e as a high-tech systems university: Beta disciplines

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EINDHOVEN UNIVERSITY OF TECHNOLOGY

Sectorplan TU/e: Science Disciplines

1. Title

Strengthening the foundations of TU/e as a high-tech systems university: bèta disciplines

2. Main applicant

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Appendices

Front cover. The "goblet of fire": activation by electric gas discharge in water. Research conducted within the department of Electrical Engineering by Wilfred Houben. Application examples of this and related research are flue gas cleaning and waste water purification. Photo by Bart van Overbeeke.

4 Summary

4.1 Eindhoven University of Technology

Eindhoven University of Technology works at the forefront of science & technology, is leading in academia-industry cooperation and aims to strengthen the basis of science and engineering disciplines to take the next step as the high tech systems university of the Netherlands. As high tech systems become more complex, are employed in a broader range of purposes and evolve towards concepts that integrate digital, physical and chemical elements, a strong basis that allows for a convergence of these fields is necessary. To do so, in strengthening the disciplines of Mathematics, Physics, Chemistry and Computer Science, TU/e focuses on three interdisciplinary fields of science that enable the next step in high tech systems: artifical intelligence in engineering, smart materials and energy & sustainability.

4.2 Mathematics in Eindhoven

Mathematics in Eindhoven is one of the largest mathematics communities in the Netherlands. Both research and teaching are of the highest level: the 2015 research assessment gave Eindhoven a perfect score of 1.0, and Mathematics boasts a wide range of high-profile prizes and grants, among which 14 Vernieuwingsimpuls grants since 2011, three ERC grants, a KNAW member and two KNAW Young Academy members, the NETWORKS Gravitation program, and a large number of other national and European grants. In teaching, the Bachelor and the Master in mathematics are among the best in the Netherlands (Keuzegids 2018/2019), the subdepartment is responsible for the wide range of mathematics courses at TU/e, and is a local and national leader in the development of ICT-enriched teaching.

The success of Mathematics in Eindhoven springs from an intensive contact between fundamental curiosity-driven research and real-world challenges. As just one example, an improved method for early diagnosis of diabetes was obtained by theoretical Lie-group analysis in collaboration with the company I-Optics. Long-term collaborations include ASML, Philips, Signify, NXP, Thermo Fisher, Shell, MUMC+, and the Catherina Hospital. These collaborations lead to fundamental mathematical advances that provide real benefit to society. In the words of the 2015 research assessment, 'The committee compliments the research unit on the large number of industry cooperations and the high mathematical quality of work that is done in such cooperations.'

Two fascinating developments will thoroughly reshape both our fundamental research and our collaborations with industry and societal partners. First, the *data deluge* is creating tremendous opportunities for mathematical approaches and learning algorithms. In particular, social and infrastructure *networks* generate rich data that must be properly analyzed in order to understand and optimize these networks. For instance, train schedules may be optimized by insight in passenger behavior, maintenance can be improved using data that machines send about their performance, and delivery services may profit from traffic data. Secondly, *deep machine learning* has proven to be highly powerful in solving seemingly intractable problems, such as playing the game of Go. Yet such black-box algorithms provide no insight in how they work, and it remains difficult to interpret the results or assess their quality. As machine learning proliferates in science and society, it is urgent to develop a fundamental understanding of the problems it can and cannot solve. This understanding requires a mathematical approach.

These two research directions align directly with the four national *focusgebieden* on *Statistical Learning, Networks, Dynamic Data,* and *Optimization & Uncertainty Quantification,* as well as with our own departmental themes on *Data Science, Computational Science,* and *Networks* with Computer Science, and the university-wide cross-disciplinary research theme *Artificial Intelligence in Engineering*.

Our ambition is to reinforce and extend our current disciplinary strengths – our three *zwaartepunten Analysis & Scientific Computing, Discrete Mathematics,* and *Stochastics* – and align them more strongly with the above two challenges. We plan to open and fill twelve positions in total; seven positions listed below with *sectorplan* funding, and five other positions by different means of funding (e.g. through retirements). The positions for networks extend our current strengths in Stochastics, while the positions in mathematics for machine learning reinforce our strengths in the other two *zwaartepunten*.

Challenge: Data Analytics and Networks	**Challenge: Mathematics of Machine Learning**
HGL Statistics for Networks	TT Robust Optimization
TT Statistics and Random Networks	TT Algorithmic Techniques for Discrete Optimization
Network Data Lab Engineer	HGL ML in Computational Science
	TT ML-Enhanced Computational Modeling

The proposed positions also are urgently needed to meet the demand generated by the sharp increase in student numbers. Student enrolment has doubled since 2011, both in mathematics and

across the university, because of strong and growing industry demand for mathematicians, data scientists, and engineers in general. The mathematics faculty, which devotes two-thirds of its teaching to non-mathematics students, needs to expand in order to maintain quality. These positions will also strengthen our role in the ambitious plans on Data Science at TU/e, including a new master program on Data Science at our own department with focus on data analytics.

We will also use these plans to increase diversity, especially in gender. We have already started a process to advertise our positions in a way that is strongly aimed at attracting female candidates, to train recruitment staff, to actively approach candidates and to actively facilitate career opportunities for partners. A first round of interviews with female candidates is currently being planned. Our aim is that at least 50% of the *sectorplan* positions will be filled by female candidates; all positions opened after May 15th will be embedded in the new Irène Curie Fellowship program of TU/e, which implies that these positions will be restricted to female candidates for 6 months, and new hires will be given a start-up package of 250-700 kEuro.

4.3 Physics in Eindhoven

Two urgent societal challenges are the energy transition and information technology. In the national physics *sectorbeeld*, 6 *focusgebieden* are defined, of which two relate to these challenges: Energy & sustainability and Quantum materials & technologies. The strengths of our *zwaartepunten* enable our department to face these two societal challenges, so we will foster the two corresponding *focusgebieden*. They also correspond one-on-one with two of the TU/e's cross-disciplinary research themes: Energy & Sustainability and Artificial Intelligence in Engineering.

We are the only university that has made the *focusgebied* Energy & Sustainability to its core activity. That is why we take the lead in various areas of energy conversion and energy storage. We are well equipped to do so by using all of our three *zwaartepunten*: FLOW, PLASMA and QNANO in the areas of fusion, plasma technology, membranes and permeable media, and in energy-saving information technologies (photonics). The DIFFER institute has moved to the TU/e campus in 2015, mainly because of the potential collaboration opportunities. The now already existing collaboration with DIFFER will be further enhanced by new joint appointments and joint projects on energy research.

In the *focusgebied* Quantum materials & technologies we aim at contributing to the societal needs of the information technology by fostering quantum technology in two different approaches: solid state devices and Rydberg clusters created in ultracold plasmas.

We have realized that there is a great potential for innovative cross-cutting research at the interface of complex fluids and soft (bio)matter. Therefore, well before the *sectorbeelden* were conceived, we already combined our efforts in these two sub-disciplines in our *zwaartepunt* Fluids, bio and soft matter (FLOW). This entire *zwaartepunt* is part of the national *focusgebied* Complex systems, soft matter & fluids, and that *focusgebied* is the third one we will foster in this *sectorplan*.

The discipline of physics within TU/e is active in 5 of the 6 national *focusgebieden*. For the above reasons, however, in this *sectorplan* we will only foster the aforementioned three of them. This is reflected in the number of new positions we apply for: primary focus is on Energy and Sustainability (5 positions), and secondary focuses are on Complex systems, soft matter & fluids and Quantum materials & technologies (2 positions each). The *focusgebied* Precision measurement & fabrication is fostered indirectly: one of the proposed positions also has aspects in this *focusgebied*.

In the alliance UU-TU/e-UMCU we will we will start joint research and education in soft matter physics, permeable media (Darcy Center), and metaphotonics. The two institutes both invest in these areas and are complementary: joining forces will accelerate scientific breakthroughs in the related *focusgebieden*.

The recent Research Review (Onderzoeksvisitatie, December 2018) clearly judged the quality of our department to be outstanding. It considered the department excellently prepared to face the above-mentioned societal challenges. The review results were 1.5 for Research quality, 1.0 for Relevance to society, and 1.5 for Viability. Furthermore, almost all full professors have a personal grant like VICI or Pionier, several ERC Advanced, Consolidator and Starting grants are active, and 4 members of KNAW and one Spinoza laureate reside in the department. One Zwaartekracht program is coordinated by the department, and many projects are active in collaboration with industry and societal organizations (NWO TTW Perspectief, Topsector TKI contracts, H2020, and the like).

The overall citation performance of the Faculty is of a very high impact level, with an MNCS value of 1.70 and 19% of top 10% highly cited publications. Our multidisciplinary physics papers have an even higher MNCS: 2.24 for the Department as a whole. This last fact illustrates that the strong foundation of our *zwaartepunten* enables us to perform excellent research also in multidisciplinary programs like

in the TU/e Cross Disciplinary Research Themes, and with industry. Strong cross-disciplinary research requires even stronger disciplinary foundations.

At this moment, the department has 55 scientific staff members, 8 of them female. Among our PhD students 35% is female. Among the 14 tenure trackers who started in the department in the last 6 years, 50% was female. At the moment, 15% of the staff is female. The department's aim is to increase that to a self-sustaining percentage of 30% in 2028. All of the 9 proposed new positions will be embedded in the new Irène Curie Fellowship program of TU/e, which implies that all positions are recruited simultaneously and will only be only open for female candidates for 6 months. Since the recruiting process has already started and high level female candidates are being identified, the discipline is confident that at least 50% of the positions (but preferably more) can be filled with female candidates.

4.4 Chemistry in Eindhoven

Chemistry at TU/e aspires to maintain its top position in research and education in *Sustainable Process Technology*, *Materials Chemistry & Functional Materials* and *Complex Molecular Systems*. The new investments in personnel will be focused on societal challenges concerning energy, circular economy and next-generation adaptive materials that will radically change our life. We will need sustainable chemicals and fuels, new materials to convert and store energy, recyclable polymers, and smart materials that enhance contact between humans and robots. The two departments involved – Chemical Engineering & Chemistry and Biomedical Engineering – foster frontier research by attracting talented scientists in a number of key areas that contribute to these ambitions. Their academic staff provide excellent education in BSc, MSc, PhD and PDEng programs. The chosen focus areas are perfectly aligned with the national Chemistry focus areas and cover the NWA routes *Energy Transition, Circular Economy, Materials – Made in Holland*, and *Regenerative Medicine*.

Scientific excellence is rooted in the quality of the staff as underpinned by high citation metrics, participation in 3 national Gravitation programs, i.e. Functional Molecular Systems, Multiscale Catalytic Energy Conversion, and Materials-Driven Regeneration, many personal national and international grants and scientific awards, the endowment of senior staff and a strong international perspective. Besides a high level of 2nd tier funding, our researchers are also very successful in connecting fundamental knowledge and applied research teaming up with public and private partners in 3rd tier funding. This is evident from the vast and intensive collaborations with private partners through bilateral contacts and public-private partnerships at the national and European level. For instance, 9 TU/e researchers in this discipline are elected members in the ARC Chemical Building Blocks Consortium (CBBC). The departments are strongly involved in biobased/biomedical programs at Chemelot Inscite (>10 M€ raised in 5 years). TU/e Chemistry is a breeding ground for start-ups (e.g., 3 Gouden Kiem Awards in 2016–2018). Combined, the national and international scientific and societal impact is apparent from (i) the recognized high quality research staff and frequently honored excellent research, (ii) the >100 highly qualified masters in chemical and biomedical engineering as well as more than 60 PhD and 25 PDEng degrees awarded on an annual basis, (iii) knowledge valorization by a high volume of 3rd tier funding in the form of contract research, start-ups and public-private partnerships and (iv) a contribution to the regional knowledge ecosystems Brainport and Chemelot. A strong national collaboration network is established via gravitation programs, the ARC CBC and the Strategic Alliance with Utrecht University and the Netherlands School for Chemical Biology. The Chemistry discipline significantly contributes to teacher education, has established a strong link with HBO institutes and is actively engaged in outreach to the public.

The *sectorplans* will be used to strengthen the Chemistry discipline with pivotal expertise in selected focus areas (total 8 positions, aligned with national partners) to (i) maintain a leading scientific and academic position in a rapidly changing world with the primary goal to offer our students the best possible learning experience, (ii) to cultivate a more horizontal research culture with clear career paths for talented staff and (iii) to balance the female/male ratio. The positions also fit in TU/e's cross-disciplinary research themes *Smart Materials* and *Energy and Sustainability*. For Sustainable Process Technology, the new positions will address the challenges faced by the chemical industry and society as a whole in the energy and sustainability transformation. In Materials Chemistry & Functional Materials, selected positions will extend the scope of supramolecular organic chemistry towards energy conversion and address the grand challenge of recyclable polymers. For Complex Molecular Systems, the design of smart nanosystems applicable at the interface of chemistry and biology requires strengthening theoretical modeling activities and developing immunomodulation concepts for biomedical applications.

In the last few years, new scientific staff has been selected on the basis of scientific excellence, early independence for optimum career development and fit with the open collaborative culture, characteristic for the Chemistry discipline at TU/e. This strategy is already applied and will be continued in the current search for potential candidates for *sectorplan* positions and is complemented by clear goals to improve

gender balance. As an example of good practice, the Chemistry discipline installs broadly composed search committees identifying in a broad area of expertise potential candidates with a special attention for female talent. Through this approach, the discipline has been able to attract 3 outstanding female scientists out of the last 4 hires in the last 6 months.

4.5 Computer Science in Eindhoven

Computer Science in Eindhoven, CS/e for short, is part of the Department of Mathematics and Computer Science at TU/e, and it is one of the larger computer-science departments among the Dutch universities. Research varies from curiosity-driven to applied, and there is an extensive and fruitful collaboration with industry. CS/e has structured its research into four themes: *Data Science, High-Tech Systems, Cybersecurity,* and *Complex Networks.* We intend to strengthen two of those through the *sectorplans*. Out of the seven national *focusgebieden*, CS/e plans to invest in *Algorithmics, Machine Learning* (ML), *Security and Privacy* (S&P), and *Networked Computer and Embedded Systems* (NCES). CS/e maintains an excellent position in these *focusgebieden*. Personal grants over the last 5 years within Algorithmics and ML include 4 VI, 1 ERC and 1 PI in the gravitation project NETWORKS. NCES and S&P are more applied and obtain significant funding from European sources, NWO TTW (STW) and direct funding through companies. Roughly 50% of the CS/e budget comes from external sources. The investments in the four mentioned national *focusgebieden* will be used to further strengthen the themes Data Science and High-Tech Systems, for which Eindhoven is a recognized center. Some of the new positions are on the interface with the themes Cybersecurity and Complex Networks. The recent growth in student numbers has led to a *numerus fixus* for Computer Science and to an overload of the staff. The new positions shown below are urgently needed to resolve this situation, in particular because our new Data Science programs are expected to grow rapidly in the coming years.

Data Science	Focus	**High-Tech Systems**	Focus
Responsible Machine Learning	ML	Engineering of Software-Intensive Systems	NCES
Visual Analytics	ML	Distributed Self-Managed Systems	NCES
Data Privacy and Security	S&P	Security for the Internet of Things	S&P
Natural Language Processing	ML	Algorithmic Aspects of Robotics and Manufacturing	ALG
Distributed Data Analysis	ALG		
Causal Discovery	ML		
Bayesian Machine Learning	ML		

The Department has the ambition to be the main center for data-science research and education in the Netherlands. The *sectorplan* can provide the means to achieve this. The TU/e fully supports this ambition, and has made *Data-Driven Intelligent Systems* one of the cross-disciplinary research themes (CRTs) in its Strategy 2030. Strengths in CS/e include Process and Data Mining, Visualization and Algorithmics. An important direction started in Eindhoven is *Responsible Data Science,* which addresses accountability, confidentiality, transparency and fairness in data science and is a topic in the NWA (route VWData). A full-fledged curriculum on data science – BSc, multiple MSc, and post master programs – has been established over the last few years, in cooperation with Tilburg University and under the umbrella of the Jheronimus Academy of Data Science (JADS). CS/e also teaches a course on Data Science to all first-year TU/e students (2500). Seven positions in the theme Data Science are requested, in the *focusgebieden* ML, Algorithmics and S&P, that extend and complement our current research strengths and that are required to further support our new educational programs. The theme High-Tech Systems is strongly connected to the industry in the Brainport Eindhoven region, and fully aligned with the CRT Complex High-Tech Systems in the Strategy 2030 of the TU/e. The focus of CS/e within High-Tech Systems is on cyber-physical systems and their engineering. We wish to expand our existing programmatic collaboration with the larger industries in the area, and our research into software- and system-architecture. Like the Data Science theme, the High-Tech Systems theme has dedicated educational programs linking to it, namely our programs on Embedded Systems, and on Automotive Systems. Within the High-Tech Systems theme we have many part-time professors from companies and research institutes. Four positions are requested to further support this theme, in the *focusgebieden* NCES, Algorithmics and S&P. The latter position fits within the (large) NWA proposal on Security for the Internet of Things that Eindhoven leads, and it links with the theme Cybersecurity. The plans of CS/e have been synchronized with Utrecht University, University of Twente and TU Delft, and discussed with other computer-science departments in the Netherlands through the Informatica Platform Nederland (IPN). Most importantly, CS/e emphasizes Machine Learning in the *sectorplan*, rather than Artificial Intelligence in its broadest form. CS/e will use the plans to increase diversity in a broad sense, including gender balance. The aim is that at least 50% of the new positions contribute to this diversity goal by a 'diversity first' approach in hiring. The new Iréne Curie program is part of the strategy in this regard.

5 Preamble: TU/e Research and Education context

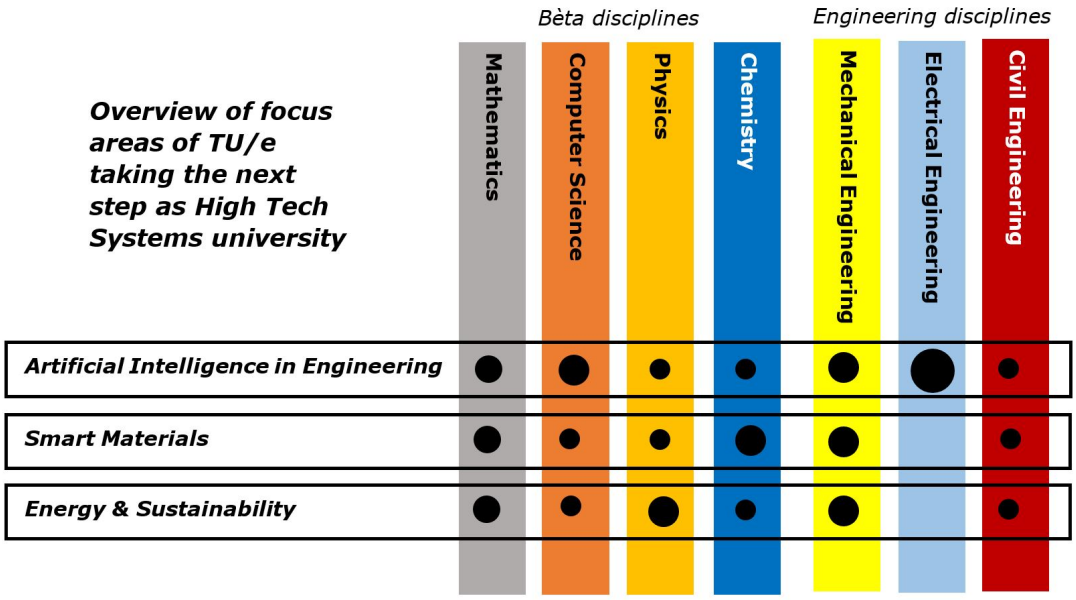
5.1 Eindhoven University of Technology

TU/e aims to contribute to a better and more sustainable future by subscribing to the United Nation's Sustainable Development Goals. TU/e acts as a science and engineering university contributing practical solutions to the complex challenges posed by many of these sustainability goals. The *sectorplan* investments will be used to further establish TU/e as the High-Tech Systems University of the Netherlands. TU/e is already of key importance for the Brainport ecosystem where some of the world's most advanced intelligent machines and electronic systems are developed. More than 80% of the NL-trained Brainport engineers have been educated at TU/e. To ensure that TU/e can continue to supply society with innovative minds in the coming decades, the TU/e Strategy 2030 aims to invest in Bèta and Engineering disciplines as well as cross-disciplinary research themes that connect these basic disciplines to solutions for society.

A common umbrella for these investments made by TU/e and the Bèta and Engineering *sectorplans* are three cross-disciplinary research themes, which form the pillars of the TU/e as a High-Tech Systems University:

1. Artificial Intelligence in Engineering
2. Smart Materials
3. Energy and sustainability

The relation between the underlying disciplines and these themes is indicated in the scheme below highlights the investments of the *sectorplans*, with the size of the circles corresponding to the number of positions on that cross-over point.



Artificial Intelligence in Engineering
High-Tech Systems are larger systems constructed using advanced hard- and software aimed at performing complex tasks. These systems have to operate in a dynamic and changing environment, including situations and configurations that were not envisioned at design time. The design of such systems not only depends on optimization of the individual components, but also the quality of the interactions between these components and the systems environment. In other words: modern high tech systems need artificial intelligence. We have to take a broad perspective, go beyond artificial intelligence as data science, and develop digital, physical and chemical systems in unison. The resulting systems approach is a unique aspect of an engineering university. We integrate chemical and physical technology, functional materials, advanced sensing and actuation systems, related data science and intra- and inter-system communication aspects in a way that makes us unique as the High-Tech Systems university. The importance of the systems approach is evident for the industry in the Brainport region, and is also increasingly relevant to other areas of our society in which complex challenges arise such as the energy transition and health.

- The Bèta *sectorplan* positions strengthen disciplinary research fields such as data science, ma-

chine learning, complexity, chemical technology, quantum technology, photonics, fluid dynamics, and plasma technology, which form the basis of the systems approach.
- The Engineering *sectorplan* positions will lay the foundation for the next generation of intelligent machines and other mechatronic/electronic systems. This will encompass fields such as hardware design, imaging, software implementation and optical and wireless communication.

Smart Materials
Smart Materials are materials that accurately and robustly meet pre-defined characteristics of a large and demanding variety. They require a profound understanding of the underlying chemistry and physics at various length scales during production, processing, use and reuse. TU/e has a very strong position in (smart) materials through its research in the departments of chemical engineering and chemistry, mechanical engineering and applied physics. The Dutch industry relies on this kind of expertise in facing the materials challenges they encounter in the context of advanced responsive materials, recyclable materials and biomaterials.

- The Bèta *sectorplan* positions focus on new concepts for next-generation adaptive (bio-inspired) materials, supramolecular inorganic and organic materials chemistry, photonics and spintronics. These materials will contribute to solving the energy challenge by developing materials and processes to help to convert, store and reuse energy, to close materials cycles in society by a.o. developing recycle concepts for polymers, and smart adaptive materials that enhance contact between humans and robots as well as bio-inspired and bio-compatible materials that can contribute to healthy ageing. A central expertise at TU/e is the use of (supra)molecular control of matter to reach desired meso- and macroscopic functionalities. Smart materials are also at the core of modern communication and computing technologies like quantum technology and integration of photonics, spintronics and electronics.
- The Engineering *sectorplan* will focus on programmable changes of materials over time (the 4th dimension), and on multi-material additive manufacturing methods, where physical and material properties of material systems are optimized for application in areas ranging from buildings to biotissues.

Energy and Sustainability
Energy and Sustainability is a theme that has a central position in the TU/e *sectorplans* for chemistry, physics, mechanical engineering and civil engineering. Major challenges relate to the efficient storage and reuse of stochastically available renewable energy sources and closing materials cycles. For supporting the energy transition, TU/e will develop new energy storage and conversion technologies to supply society with ubiquitous sustainable energy. Metal fuels, heat storage and chemical conversion are the three pillars of the recently founded Institute for Renewable Energy Storage (IRES). TU/e's strong position in research in energy and sustainability is further enhanced by the presence of DIFFER on its campus. The research directions at TU/e have complementary counterparts in DIFFER, so the already existing intensive collaboration in the areas of fusion, chemical conversion, energy storage and porous media will be strengthened further by shared positions and joint programs. In addition, civil engineering structures such as wind turbines, solar farms in open field and solar panels on building roofs, are developed and optimized with respect to energy generation, storage, distribution and demand reduction.

- The Bèta *sectorplan* positions cover the fields of chemical conversion (sustainable chemical industry, separation technology, storage renewable energy), nuclear fusion and photovoltaics.
- The Engineering *sectorplan* focuses on thermal energy storage, on wind and solar energy, and on energy storage in porous materials and metal powders.

5.2 Partnerships

The UU-TU/e-UMCU alliance was initiated several years ago to become leading in selected topics such as Energy and Health. The alliance has established and intensified joint research programs since 2011. In the near future, the alliance will be extended with WUR. Section 5.8 provides more details on this alliance. Other relevant partnerships are the 4TU.federation and EuroTech Universities. The 4TU.federation (TU/e, TU Delft, UTwente and Wageningen University & Research) encompasses the collaboration of the Bèta and engineering disciplines in 10 4TU.Centres and research schools. Under the umbrella of the 'High tech for a sustainable future', research programs are defined on topics such as health-oriented design, resilience engineering, internet of plants and soft robotics. In the EuroTech Universities Alliance (TU/e, DTU Copenhagen, TU München, EPFL Lausanne, Ecole Polytechnique Paris and Technion Israel), strengths are combined in collaborative PhD and Postdoc programs and projects in areas such as data science, energy, photonics, health and mobility.

A few years ago, JADS (Jheronimus Academy of Data Science) was established together with Tilburg University with three campuses: Eindhoven, Tilburg and Den Bosch.

5.3 Cooperation with industry

TU/e aims to provide the world-class education and research that constitutes the life-line of the Brainport world-class high-tech ecosystem. More than 80% of the Dutch newly graduated engineers that start working in Brainport are educated at TU/e. TU/e is also world-leading in cooperation with industry as evident from the many professors-of-practice, the large number of collaborative scientific papers with industry and the high volume of 3rd-tier funding. Close to a quarter of private R&D in the Netherlands (~2 billion euro is performed in Brainport. TU/e has created flagship initiatives with industrial and societal partners such as Philips, ASML, NXP, VDL, Océ, hospitals, and companies in the vast supply chains of the high-tech industry. In addition to this, TU/e has also many other strong collaborations such as with Shell, DSM, SABIC, AkzoNobel, Nouryon, BASF, Dow, FrieslandCampina.

5.4 A growing demand for education

The main educational ambition of the Bèta disciplines is to deliver well-trained engineers with a clear societal perspective through dedicated BSc and MSc programs. The BSc programs are embedded in the TU/e Bachelor College that provides the students a broad disciplinary base with a strong attention for technological, societal and economic aspects. Through a strong link with the research carried out in the departments, the MSc programs provide future engineers a sound scientific and practical basis to continue their studies in a suitable PhD program or PDEng program, or enter the professional field.

The sharp rise in the number of students enrolled at TU/e (from 7,300 in 2010 to 12,200 in 2018 and projected to grow to 14,500 in 2022 is very much needed to cover increasing and persistent shortage of qualified engineers, which is experienced throughout the Dutch economy and especially in the Brainport region. The student population is diversifying with an increasing number of international students and students transferred from high professional education. The predominantly junior new staff will contribute to a further modernization of education programs and also establish a better link to societal demands. All these elements fit well with the educational view formulated in the Strategy 2030.

The increased number of teachers made possible by the *sectorplans*, combined with the already mentioned implementation of the modern, e-based methods in the curricula will contribute to an increase in the overall educational capacity of TU/e, while maintaining the high overall quality of TU/e's education with its specific hands-on character. In the Bèta disciplines, there is a numerus fixus for Computer Science. TU/e will increase the enrolment in computer science as a result of the *sectorplan* investments. Though it is our aim to eliminate barriers when possible, applications for Computer Science are well above current and future capacity and a numerus fixus is maintained for this moment.

5.5 Matching of Sectorplan positions by TU/e

To accelerate impact of the *sectorplans*, TU/e has reserved funds to support the *sectorplan* areas. These include the 2% *Profileringsmiddelen* (1.5 M€ per year), and TU/e tops that with extra central funds to a total of about 6 M€/year to supplement the *sectorplans* (item 1 and 2) and a fellowship fund to improve the gender balance at TU/e (item 3).

5.6 Fostering research talent: recruitment and diversity

TU/e implements a broadly supported modern gender and diversity strategy striving for a balanced international staff to support an overall inclusive and international environment with at least 1/3 of its students to be international by 2023, and 25% of its research staff to be female by 2023.

- A recruitment team helps the departments in the hiring process and safeguards, together with the diversity officer, gender and diversity issues. The recruitment team also assists in gathering the information (e.g. publication and citation records) on potential candidates on long lists, and by channeling the paperwork and logistic flow of the recruitment process. Furthermore, they are developing material to be broadcast to the outside world that informs potential candidates on TU/e's merits as an employer;
- Active gender-balanced search committees of young professors within (sub)disciplines have been installed to prepare long-lists of candidates using their own networks
- Specific measures are to appoint at least 50% women at the UD level, to train staff in recognizing gender and cultural bias and to advertise positions in an open manner engaging a broad range of candidates.
- To limit final drop-out of female candidates by dual career challenges, TU/e introduced the Dual Career Opportunity program for spouses which makes use of the Expat Spouses Initiative (ESI) in the Brainport area; the recruitment organization will also actively connect to companies like ASML, Philips, NXP, VDL and DAF;
- In seeking new staff, key criteria such as a strong drive and enthusiasm to contribute to excellent research and education in a collaborative environment and the ambition to develop into an independent researcher are more important than an exact fit to a described profile.
- All departments use the same approach in the hiring process by appointment committees in which at least two female researchers, one researcher from outside the department and, for Bèta, a member of the interdepartmental committee Bèta Sciences participate.
- On May 1, 2019 the TU/e board introduced the Irène Curie Fellowship program (2019-2024), with the aim to boost the recruitment of female scientists further.

The *Bèta-decanen* will work together on increasing gender diversity and on making the recruitment for the *sectorplan* positions a success. Particular actions envisioned are:

- Exchange of best practices in recruitment in general and diversity in particular amongst all Bèta faculties. This will be done in special sessions, involving not only deans, but also HR staff.
- A list has been prepared of all *sectorplan* positions. This list will be used to advertise these positions on specific occasions, for instance in the UK, where the Dutch embassy has offered to help us target Dutch scientists who wish to leave the country. This list will also be used to help us refer candidates less suited for a position at a specific faculty, to one of the other faculties.
- Whenever possible, we will work together on solving dual career situations of incoming candidates.
- All faculties will advertise shorter and broader descriptions of the *sectorplan* positions than submitted in the original plans in order to invite a wide selection of possible candidates. This is in line with recommendations by gender experts, proven to be effective in the recruitment of female scientists

5.7 National alignment and coordination

We foresee that national alignment per discipline and focus area first of all will take place within disciplinary forums, namely PWN for Mathematics, IPN for Computing Science, and two new platforms for Chemistry and Physics. The 'Bètadecanenoverleg' will regularly ask these platforms to reflect on the overall progress within the disciplines and the focus areas and identify new developments and opportunities for collaboration. This will be the input for discussions of the national strategy with the *sectorplan* Committee.

5.8 UU-TU/e-UMCU alliance

The current alliance exists already since 2011 and has recently been strengthened by allocating substantial funds in areas of complementary research between the three institutions. The goal of the

alliance is to strengthen scientific excellence and societal impact on specific cross-disciplinary topics and offer education in these fields. Within the fields of Energy and Health, multiple large research programs have been initiated and intensified. Specifically, efforts are being developed to use plasma treatments in regenerative medicine, particularly aiming at understanding the fundamental interaction between cold plasmas and living tissue. Researchers from the UMCU, Utrecht-Chemistry and TU/e-Physics are involved in this project. A second large project builds on an earlier alliance collaboration in the field of solar fuels in which catalysis researchers from the Chemistry discipline of both universities work on the challenge of renewable energy storage. In this regard, substantial funds were made available to hire additional staff on top of staff investments made within the gravitation program Multiscale Catalytic Energy Conversion. Within this initiative, new routes for the efficient conversion of renewable energy sources to chemical energy are being explored, in view of the development of key technologies required for the global energy transition. This joint effort is perfectly aligned with the IRES initiative of the Energy and Sustainability research theme described above.

At present, a new alliance program is being set up, including Wageningen University & Research, that will enable our four institutions to engage scientific and societal challenges in the broad fields of life sciences and engineering. A select number of initiatives will be chosen to create a leading and innovative position, in correspondence with the above mentioned *zwaartepunten*: artificial intelligence in engineering, smart materials and energy & sustainability.

Other concrete opportunities arise around the local strengths in the complexity theme. The Institute for Complex Molecular Systems (ICMS) at TU/e is world-leading in multidisciplinary research involving complex molecular systems, and has recently launched a focus area on 'Grip on Complexity' to study complex systems from an engineering perspective, with methodology focusing on networks and dynamics and control. Complementary to this, the Center for Complex Systems Studies (CCSS) at UU is renowned for studying the fundamental perspectives of complexity in mathematics and physics, and ranging to applications particularly in climatology and economy, but also epidemiology and social sciences. Aspects such as networks and control are shared between these institutes and are populated with new staff in the *sectorplans* (for example in mathematics at UU), and through strategic funds at the TU/e side.

In analogy with these large alliance initiatives, the two universities will also stimulate new groups of (*sectorplan*) positions to form the core of additional alliance programs for which funds. Bilateral exchange of personnel by mutual appointments as part-time professors is already in place, and will be extended further.

On-boarding
Once the new *sectorplan* positions have been filled, the issue of on-boarding becomes dominant: the new staff members have to find their way in the Dutch and EU research grant organizations, they have to discover the institute's and national disciplinary organizations, and they have to learn how to live and work in their new home town. In this on-boarding process, the research support structure plays a pivotal role.

Both universities have their own research support structures. At TU/e, the Innovation Lab has a very good infrastructure for supporting business creation and for acquiring 3rd tier funding. PI's are assisted in composing business plans, installing proper management and administrative structures, etc: everything that is required for setting up spin off companies. Furthermore, the TU/e innovation lab has legal and administrative personnel to take care of contracts and forms for contracts with industry and the EU. The TU/e Holding B.V. often assists as a buffer company. Furthermore, TU/e has a good network in Brussels through the Eurotech alliance, in which EPFL, Ecole Polytechnique, Technion, DTU and TUM participate. At UU, there is a very good infrastructure for acquisition of 2nd tier funding. UU RSO staff is assisting the PI's in the selection of the appropriate funding channel, but also in structuring the proposals: they are in fact co-writing with the PI's. At UU, a training mechanism is in place to train new RSO-officers in these skills.

For facilitating the *sectorplan* PI's in their career development, these two complementary expertises are going to be merged. TU/e RSO staff will be able to follow the dedicated training of the UU officers in acquiring 2nd tier funding. On the other side, UU PI's can make use the TU/e's expertise in business development and the acquisition of EU funding. In this way, optimum support can be given to the new (and of course also existing) personnel: on both sides there will be optimum support for acquiring 2nd tier funding as well as 3rd tier funding and business development.

Recruiting
Both universities have stepped up their recruiting efforts to accommodate the coming inflow of new staff that will be hired on the *sectorplan* (and other) positions. The two recruiting teams have met and will share each other's best practices. These best practices encompass aspects like advertisements,

scholarships, on-boarding, mailing lists for (female) candidates for each discipline, etc. A dominant aspect of recruiting in the Bèta-sector, especially when recruiting and appointing female candidates, is in the dual career challenge. Here, the two universities will operate jointly. TU/e has already set up a connection with the Expat Spouses Initiative (ESI, http://expatspousesinitiative.org/ The ESI has a very good network in the Brainport area, not only with large industry, but also with SME's. Furthermore, the TU/e recruiting team is setting up separate connection with companies like ASML, Philips, NXP, VDL, etc. The combination of UU, with its large scope of academic jobs in all disciplines (Bèta, but also law, medical, and SSH), TU/e with its pool of jobs in Bèta and technique, and the Brainport region with its thousands of R&D positions in industry, will have a good starting position in facing the dual career challenges.

Potential New Alliance programs
The new staff positions that are going to be installed at both institutes open the opportunity to extend the alliance with new programs. A short list is given below.

Light-matter interaction is the common denominator of 7 *sectorplan* positions at TU/e and UU, and they are well suited for collaboration and joint recruiting. A potential vehicle for this is the Institute for Photonic Integration (IPI) and the associated gravitation program on Integrated nanophotonics.

Catalysis is already the basis of one of the ongoing alliance programs. UU-chemistry requests two positions in the *zwaartepunt* catalysis, one theoretical position on the fundamental understanding of charged solid/liquid interfaces and one on understanding structure and performance of solid catalysts under relevant reaction conditions. The latter position is highly complementary with an existing position at the TU/e. TU/e-chemistry requests a position on supramolecular inorganic materials, and has recently appointed an assistant professor on multiscale modeling of catalytic processes: TU/e and Utrecht University focus on different aspects, and coordination will also take place via the MCEC, the Netherlands Center for Multiscale Catalytic Energy Conversion.

Functional Materials/Nanoscience & Hybrid Materials. Within this *zwaartepunt*, UU-chemistry requests two positions, one of which, on functional two-phase systems for interfacial catalysis, is anticipated to complement activities at the TU/e in catalysis and process engineering, like in the proposed position on Sustainable Chemical Reactor Engineering. Exchange of staff members between UU-Chemistry and TU/e-Chemistry is currently ongoing and mutually strengthens the local activities in the Chemistry of Materials focus area and enhances the interaction between these local activities.

High-dimensional systems is the core behind several positions at TU/e mathematics and UU-mathematics. The relevant teams at UU and TU/e are in the process of preparing a new Zwaartekracht program, and this alliance can foster that initiative.

Sense-making and decision-taking in interactive intelligent systems is the common denominator of 3 positions at TU/e-EE, and 2 at UU. A coordinated approach of the research of these 6 new PI's will be stimulated.

5.9 Extension of the alliance with WUR

Based on the success of the UU-TU/e-UMCU and a future view on establishing critical mass, the alliance is discussing an extension of the alliance with Wageningen University and Research. The new UU-TU/e-WUR-UMCU alliance has the potential to become a worldwide stronghold in areas of research, education, value creation, and operations, targeting societal challenges such as the energy transition, circular economy, health and food and agriculture. Key enabling technologies are artificial intelligence, data science, imaging, sensoring, complex high-tech systems, and stem cell technology. Artificial intelligence and life sciences will play a central role in the new alliance. In the area of education, the UU-WUR-TU/e Alliance is exploring options to establish highly integrated educational programs, e.g. by using e-learning, offering joint bachelors and micro-masters. The various partners have also a strongly shared view on entrepreneurship, technology transfer, providing an excellent incentive to link up the three ecosystems around high-tech, life sciences and agrifood.

MATHEMATICS

6 TU/e: Mathematics: 'Facultaire zwaartepunten'

6.1 Mathematics in Eindhoven

The vision of Mathematics in Eindhoven is that through a deeper understanding of the fundamentals of mathematics we can develop solutions to today's societal problems. Each of the three *zwaartepunten* in Mathematics is organized around a type of mathematical structure that appears in these societal problems: **Analysis and Scientific Computing** deals with *high-dimensional systems*, **Discrete Mathematics** with *discreteness*, and **Stochastics** with *randomness*. We plan to reinforce and extend our *zwaartepunten* in the directions of *Data Analytics and Networks* and *Mathematics of Machine Learning*.

Mathematics in Eindhoven forms one department with Computer Science. The department has centred its research on five themes, *Data Science, High-Tech Systems, Complex Networks, Computational Science*, and *Cybersecurity*, and the *zwaartepunten* of Mathematics contribute to the first four. Mathematics will use the *sectorplan* funds to strengthen its position in four (out of seven) national focus areas, *Dynamic Data*, *Networks*, *Optimization & Uncertainty Quantification*, and *Statistical Learning*. The requested positions strengthen the departmental themes Data Science, Complex Networks and Computational Science. These are well-connected to the three university-wide cross-disciplinary research themes.

6.2 Analysis and Scientific Computing (A&SC)

Many models of reality are high-dimensional, such as systems of many atoms or molecules, of many people and bots dealing in financial markets, or of many rays of light that illuminate a scene. The large number of particles, bots, rays, or other entities that interact with each other makes such systems difficult to understand for humans, difficult to simulate on a computer, and difficult to control. The aim of A&SC is to develop methods to deal with this difficulty, which may be theoretical methods (Analysis) or computational ones (Scientific Computing), and most often methods combining both.

Machine learning promises to have a deep impact on this field. In the design and study of methods we highly value understanding, trustworthiness, and control. Machine learning algorithms offer none of these, but have unparalleled performance in certain situations. Our long-term aim is to develop the mathematics *that will allow us to combine the best of both worlds,* and we propose a new chair on Machine Learning for Computational Science as an important first step. This new chair will contribute to the national focus areas *Statistical Learning* and *Dynamic Data*.

6.3 Discrete Mathematics (DM)

Discrete Mathematics studies finite structures and their properties. Much beautiful pure mathematics and even recreational puzzles such as Sudoko fall into this area. However, discrete mathematics is also an exciting growth area in the modern information age: just as continuous mathematics led to major scientific developments in the 19th and 20th century, Discrete Mathematics with its various subfields such as algebra, coding theory, combinatorics, computational algebra, cryptography, discrete optimization, geometry, graph theory, number theory, etc., underlies much of the developments in the virtual world, such as computer technology, communication networks, and e-commerce, as well as in the physical world, such as train schedules, secure passports, and supply-chain optimization.

Discrete Mathematics at TU/e embraces the challenge of dealing with an abundance of available data. Work in coding theory and cryptography ensures correctness and confidentiality of the data while combinatorial optimization tackles the flood of data to calculate better predictions and schedules. Machine-learning methods are rapidly gaining ground in the toolbox for optimization propblems, particularly for those problems that are data intensive, while Robust Optimization has proven itself as a key paradigm for handling uncertainty. Our strategy is to get to the forefront of this new and still evolving research topic. The proposed positions will enable us to do this, and will contribute to the national focus area *Optimization & Uncertainty Quantification*.

6.4 Stochastics (S)

Stochastics is concerned with complex processes and large-scale systems that involve randomness and uncertainty, from a statistical viewpoint, a probabilistic perspective, or an optimal decision-making standpoint. Getting a grip on these features is instrumental in managing the backbones of our society (e.g., the Internet, power grids, social networks, logistic networks, industry, health, and food), but raises formidable scientific challenges and requires sophisticated methodologies due to the inherent randomness and massive scale.

While Statistics is strongly data-oriented, current approaches in Probability and Stochastic Operations Research, particularly in the context of large-scale networks, are mostly model-based. With a mass of data from sensors and other sources, however, there is increasing need for data-driven network modelling and stochastic learning for network optimization. Our key strategic aim is to *develop a research*

thrust in high-dimensional data analysis at the crossroads of statistics and networks, to reinforce the mutual ties and be better positioned for interactions with various application domains. This is a major undertaking; we propose to create a new chair on Statistics for Networks to do this, which will contribute to the national focus areas *Networks*, *Optimization & Uncertainty Quantification*, and *Statistical Learning*.

7 Characteristics of the 'zwaartepunten' for which funding is requested

TU Eindhoven, Mathematics

Analysis and Scientific Computing (A&SC)

Scientific content: The research in *Analysis and Scientific Computing* (A&SC) in Eindhoven revolves around high-dimensional systems such as partial differential equations (PDE's) and integral equations, innovative numerical approximations of these equations, and scientifically and societally relevant applications. The Eindhoven group A&SC is particularly well known for:

1. Nonlinear PDE theory (existence, uniqueness, well-posedness), calculus of variations (gradient flows, optimal transport; Vici Peletier 2011, Vidi Peletier 2004, Vidi Tse 2018), and multiscale analysis
2. PDEs on Lie groups, with applications to image analysis and processing (Vici Florack 2004, ERC Starting Grant Duits 2014, NWO-TTW Perspetive 2017)
3. Deterministic and stochastic particle systems, particle-based simulation methods (Vidi Baumeier 2017)
4. Innovative structure-preserving discretization methods for PDEs from fluid dynamics and electromagnetics, and highly efficient solution methods for the resulting systems of algebraic equations (Vidi Hochstenbach 2013, and three NWO-TTW Perspective programs: EUROS Koren 2014, SLING Koren 2015, Free-Form Scattering Optics IJzerman 2017)
5. Model-order reduction techniques and differential-algebraic systems (Schilders with various projects in EU programs)

A&SC is member of the national mathematics cluster NDNS+.

Quality and Impact: The research in Analysis and Scientific Computing (A&SC) is of the highest quality, impact and viability. It has been awarded with many grants and prizes; in the period 2016–2018 with NWO Vidi grants for Baumeier (2017) and Tse (2018), NWO TTW Perspective Program grants for ten Thije Boonkkamp and IJzerman (2016) and Florack (2017), an NWO cluster grant for Peletier and van Leeuwaarden (2016), a FOm/v award for Fuster (2016), a CEAS Aeroacoustics Lifetime Award for Rienstra (2017), and a Philips Impact Award for postdoc Erik Bekkers (2018). 22 PhD students successfully defended their thesis in the period 2016–2018, two of them *cum laude*.

The national Shell-NWO program Computational Sciences for Energy Research (Top Sector Energy, 75 PhD students and 8 tenure-track positions) has been chaired from A&SC. A&SC successfully participates in European programs like EID, COST and ECSEL. The 2018 midterm research review committee designated A&SC as "the strongest and most coherent group in applied analysis and scientific computing in the Netherlands", and the peer committee of the 2015 research assessment concluded "In the evaluation period A&SC has been doing extremely well in combining fundamental research with a clear position towards industry and societal relevance".

The group has long-term collaborations with companies ASML, Shell, Philips Medical Systems, Signify, NXP, and Thermo Fisher, and with national and international research institutes CWI, DIFFER, ECN, NRG, MARIN, Deltares, NLR, and ESA-ESTEC. The mathematical consultancy company LIME spun off from A&SC in 2011 and is currently expanding with a branch in China.

Masters: Croho 60347: Master Industrial and Applied Mathematics

Size and intended expansion of the permanent scientific staff: The total permanent research staff of A&SC is 17.1 fte (in fte: 5.1 full-time professors, 3 associate professors, 9 assistant professors of which 3 in tenure track). In addition there are 2 postdocs and 21 PhD students. The request for expansion concerns one full-time professor and one tenure-track assistant professor, and one further tenure-track position will be funded internally.

TU Eindhoven, Mathematics

Discrete Mathematics (DM)

Scientific content: Current research in Discrete Mathematics (DM) in Eindhoven is known for:

1. Combinatorial Optimization: unifying Methods for Discrete and Nonlinear Optimization, as well as pushing the boundaries of the trade-off between solution quality and computation time. (Vici Bansal 2018, Spieksma: EuroTech 2018, KUL C2 grant 2017, FWO 2014, KUL 2013).
2. Complexity Theory and Algorithms: developing new algorithms and analyzing their complexity (Veni Nederlof 2014, Vidi Bansal 2011, ERC CG Bansal 2013).
3. Cryptography from theory to large-scale internet deployment (Vici Bernstein 2011, Veni Laarhoven 2018, five Horizon2020 projects, including a Marie-Curie network, and two European Networks of Excellence)
4. Fundamental research on discrete structures, such as Matroids, Lie groups, and discrete and tropical geometry (Veni Eggermont 2018, Vidi Draisma 2010, Vici Draisma 2016).
5. Innovation of (mathematics) education, devloping educational software.

The group is well connected within TU/e, contributing the mathematical aspects of security to Ei/Ψ, the Eindhoven Institute for the Protection of Systems and Information, and being part of QT/e, the recently established Centre for Quantum Materials and Technology Eindhoven.

The group has long-term collaborations with companies Philips, NXP, Riscure, Brightsight, PostNL, EuroTransplant, ProDrive Technologies, LIME, and ProLeague.

DM is member of the national mathematics cluster DIAMANT, and participates in NETWORKS.

Quality and Impact: Research in DM is of very high quality. This is e.g. witnessed by many high-profile grants and prizes in the past, and in the past three years Vici grants for Draisma (2016) and Bansal (2018), Veni grants for Laarhoven and Eggermont (2018), and the Stieltjes PhD prize for Jorn van der Pol (2018). The 2015 research assessment stated "DM members have an excellent record in personal grants, scientific awards, invited lectures/plenary talks, and editorships at highly ranked journals." The recently appointed CO-chair Spieksma is PI in NETWORKS, is founder and chairman of the EURO Working Group Operations Research in Sports (2015-present), was president of the Belgian Society of Operations Research (2014-2017), and has served on countless program committees.

The relevance of DM for society is well illustrated by some of the projects with societal partners. Eindhoven cryptographers have developed cryptographic algorithms (`Curve25519`, `Ed25519`, `XMSS`) that are now securing connections with browsers (Firefox, Chrome) and chat applications (WhatsApp, Signal). Lange contributed to two Fact Sheets to the National Cyber Security Center on post-quantum cryptography and internet security. Hülsing took the lead on designing and standardizing `XMSS`, a system that resists attacks by quantum computers and is the first such to be adopted for Internet use by the Internet Engineering Task Force.

Since 2006, Spieksma has been advising the Belgian football league on generating the national match schedule; other projects include designing combinatorial auctions for a housing corporation in Amsterdam, collaborating with Royal Dutch Hockey Bond on competitions without ranking (since 2019) and supporting kidney allocation decisions for EuroTransplant (since 2018).

The research in Discrete Mathematics also has a real impact on education in the Netherlands and world-wide. By combining its research on the algebra and geometry of discrete structures with modern computer-algebra software and internet technology, the group has created a highly interactive and adaptive web-based environment for *interactive mathematics*. These activities resulted in the spin-off of the company Sowiso, specialized in digital testing of mathematics, whose software is now used by TU/e and 25 other schools of higher education around the world, and by various high-school educational publishers in the Netherlands, Belgium, Norway and Sweden.

Masters: Croho 60347: Master Industrial and Applied Mathematics
Croho 60438: Computer Science and Engineering, track Information and Security

Size and intended expansion of the permanent scientific staff: The total permanent research staff of DM, in fte, is 12.2 (three full-time and two part-time full professors, three associate professors, and six assitant professors, of which one in a tenure track). In addition there are 12 PhD students and six postdocs. The request for expansion concerns two tenure-track assistant professors, and one further tenure-track position will be funded internally.

TU Eindhoven, Mathematics

Stochastics (S)

Scientific content: The research in *Stochastics* (S) at TU/e revolves around complex processes and large-scale systems that involve significant randomness or uncertainty, from a statistical viewpoint, a probabilistic perspective, or an optimal decision-making standpoint. The research agenda covers fundamental scientific challenges and methodological advances as well as societally relevant problems in various application domains such as computer-communications, energy, high-tech systems, pharmaceutical data studies, social networks and mobility. The Stochastics group specifically focuses on:

1. Reliability/survival analysis and statistical process control (Di Bucchianico)
2. Adaptive sensing, statistical learning, detection/inference (Castro, Van den Heuvel, Serra)
3. Non-parametric statistics (Castro, Serra)
4. Mixed modelling, model selection, missing data analysis (Van den Heuvel)
5. Random graphs, network dynamics, community structures (VICI Van der Hofstad, STAR/VENI Komjathy, NETWORKS Van der Hofstad/Hulshof/Van Leeuwaarden)
6. Statistical physics (van der Hofstad, Hulshof)
7. Smart maintenance (TKI-WoZ Di Bucchianico/Kapodistria)
8. Optimization in large-scale service systems (NWO TOP Vlasiou, NWO Complexity Vlasiou/Zwart, NETWORKS Borst/Kapodistria/Van Leeuwaarden) and Energy networks (VICI Zwart)
9. Performance evaluation of communication systems (NETWORKS Borst/Boxma/Resing)
10. Transportation networks and smart logistics (NETWORKS/NWO Topsector Boon/Boxma)

The Stochastics group is strongly involved in the national mathematics cluster STAR, and engages in several collaborations with a diverse range of industry partners (e.g. Akzo, Alfa Laval, ARS, ASML, CQM, DSM, HOTflo, IBM, Merck, Microsoft, MSD, NXP, Philips Health, Signify, TNO, Vanderlande, De Verkeersonderneming).

Quality and Impact: The research in Stochastics is of excellent quality, as reflected in many grants and distinctions (approval of grant for second stage of NWO Gravitation program NETWORKS, five NWO/TTW project grants, election of a KNAW Academy member, an honorary doctorate, a lifetime achievement award, two Stieltjes PhD awards, a KWG best-thesis prize, and three best-paper awards). Twelve PhD theses were successfully defended in the period January 1, 2016 to December 31, 2018, three of which cum laude.

Stochastics actively participates in a wide range of application-driven and society-oriented research programs, at TU/e level (e.g. Impuls projects Intelligent Lighting, Healthcare Smart Maintenance), at a national level (e.g. 4TU High Tech for a Sustainable Future, 4TU Resilience Engineering Center, NWO Big Data Real Time ICT for Logistics, NWO Complexity, NWO TA-COAST, NWO-Topsector Sustainable Logistics Dynafloat, NWO-TTW Rapid Micro Statistics, TKI-WoZ Daisy4OffShore), and a European level (Delphi4LED, Prophesy).

The 2015 research assessment committee stated "In the STO research program there are a number of excellent researchers in probability, making the department internationally very well recognized. They work mainly in queuing theory and statistical physics, with a good balance between fundamental and applied research. The high societal relevance of research by members of STO is reflected in publications in top journals from other fields than the core discipline and in a part-time position of a member at Alcatel-Lucent". The 2018 midterm research review committee concluded "STO is exemplary in the field of probability and stochastic operations research, with a good balance between fundamental and applied work; the latter group may be unequalled in quality and size".

Masters: Croho 60347: Master Industrial and Applied Mathematics.

Size and intended expansion of the permanent scientific staff: The current total permanent research staff in Stochastics is 13.5 fte (3 full-time and 5 part-time full professors, 3 associate professors, 6 assistant professors). In addition, there are 2 lecturers, 2 postdocs and around 20 PhD students. The proposed expansion concerns one full professor, one associate/assistant professor, and one lab engineer covered by *sectorplans* funds, and three further associate/assistant professors in the area of Stochastics covered by other departmental budgets.

8 Requested positions

As described above, the ambition of Mathematics in Eindhoven is to align and strengthen our current strengths, the three *zwaartepunten*, in the direction of the two challenges of *Data Analytics and Networks* and *Mathematics of Machine Learning*.

8.1 Analysis and Scientific Computing

The field of A&SC has a long and successful model-driven tradition, building descriptions of reality by combining first-principles modelling, perturbation analysis, well-chosen simplifications, and numerical approximation; in this tradition data plays only a minor role. This contrasts strongly with the trend in machine learning, in which data is considered sacred and modelling assumptions are kept to a minimum. In recent years these two philosophies have started to mix, with machine-learning models acquiring more modelling structure, and numerical simulations incorporating neural networks as tools and components.

A&SC is pushing ahead this development: machine-learning algorithms are now studied as tools in Scientific Computing (discretization, interpolation, latent variable generation), as problems in the Calculus of Variations, and as models for Artificial Intelligence. Our long-term ambition is to develop the mathematics that allows us to combine the strengths of model-based and data-based science.

To further accelerate this trend we will invest strategically in this area through a new chair Machine Learning in Computational Science, consisting of a professor and two tenure-track positions; two of these positions we put forward for *sectorplan* funding. The new chair will be part of the national *focusgebieden* Statistical Learning and Dynamic Data, will be part of the TU/e-wide AI initiative, and will collaborate with the AI and ML groups in Computer Science. In contrast to other mathematical machine-learning developments at TUD, UL, and UT, the Eindhoven chair will be specifically focused on the role of machine learning *in the context of Scientific Computing.*

8.2 Discrete Mathematics

Discrete Mathematics at TU/e has a strong history of developing for the needs of society and industry. Recently, Spieksma was hired to reinvigorate the applied aspects of Combinatorial Optimization (CO). We intend to further strengthen CO in Eindhoven through tenure-track appointments in Robust Optimization, Algorithmic Techniques for Discrete Optimization, and Computational Integer Programming. These positions belong to the national *focusgebied* Optimization & Uncertainty Quantification. We apply for funding of the first two via the *sectorplan* and fill the third via department funds.

While Robust Optimization currently deals with parameters that are allowed to vary within a so-called uncertainty set, societal network data sets lead to a class of optimization problems where the (huge) network itself is uncertain. Developing structural results for such algorithms will be the aim of the tenure-track position Robust Optimization. As in the case of A&SC, Machine Learning methods have significant untapped potential in discrete optimization. How to use ML methods directly for optimization, or how to embed ML within a traditional branch-and-bound framework, are two basic questions, and such questions are the topic of the tenure-track Algorithmic Techniques for Discrete Optimization. The area of the third position, Computational Integer Programming, is a workhorse for solving CO problems, and serves to strengthen the expertise in Discrete Mathematics in this area.

8.3 Stochastics

Large-scale societal networks provide increasingly abundant sources of data. While data sets are typically studied through a statistical lens, network structures and dynamics have traditionally been analyzed via stochastic model-based paradigms. We propose a new chair in *Statistics for Networks* to bring these perspectives together and develop a research thrust in high-dimensional data analysis at the crossroads of statistics and networks. The abundance of network data also provides unique opportunities for data-driven modelling of network structures and optimization, and accordingly we further propose four TT positions *Statistics and Random Networks*, *Spatial-Temporal Statistics*, *Stochastic Learning for Network Optimization*, and *Bayesian Networks & Bioinformatics*. Combined, these topics will expand our core expertise so as to gain a better understanding of the statistical properties and spatial dynamics of large-scale networks, and leverage that to greatly improve their operation and reliability.

Stochastic research on high-dimensional dynamic network data also requires hands-on practical data work, such as collection, storage, cleaning, and preparation of relevant, diverse, and multi-source data. In addition to the tenure-track positions above we therefore request a Lab Engineer to support the research staff and students.

For three of these positions we apply for *sectorplan* funding, and we plan to fill the others by realigning retirements. All the positions are tightly connected to the national mathematical *focusgebied* Networks, and are further closely aligned with either Optimization & Uncertainty Quantification or Statistical Learning. The research thrust will help create new links between statistics and the NWO Gravitation Program NETWORKS and strengthen involvement in the departmental Data Science theme and interactions with various application domains.

8.4 National focus on mathematics of machine learning

The intensification of mathematical research in machine learning is happening throughout mathematics in the Netherlands. In order to stimulate and coordinate this, the clusters NDNS+ and STAR will start a national focus group on the Mathematics of Machine Learning, and the two clusters will make seed money available to start this up. The positions in discrete mathematics and machine learning have also been coordinated within DIAMANT.

Table 3: Overzicht investeringsplannen per discipline. Abbreviations: *zwaartepunten* Analysis and Scientific Computing (A&SC), Discrete Mathematics (DM), and Stochastics (S), and national focus areas Dynamic Data (DD), Networks (Nw), Optimization and Uncertainty Quantification (O&UQ), and Statistical Learning (SL).

TU/e: Mathematics: Summary of positions requested from *sectorplans* funding				
Priority	Positions	ZP	Nat. focus areas	
1	**TT Robust Optimization.** Robust Optimization (RO) deals with uncertainty in optimization problems, while preserving tractability. RO combines elements from deterministic and stochastic optimization, and provides techniques to deal with data-intensive optimization problems.	DM	O&UQ	
2	**Professor in Statistics for Networks.** Developing (Bayesian) statistical and causal models and techniques for the analysis and monitoring of social, biological, and health network and dynamic data.	S	SL,Nw	
3	**Professor Machine Learning in Computational Science.** ML has great potential as an integrated tool for Computational Science, and this requires a fundamental, mathematical approach. This chair will form a hub that connects A&SC with the AI and ML activities in Computer Science and with the Institute for Complex Molecular Systems.	A& CS	DD, SL	
4	**TT ML-Enhanced Computational Modelling of Complex Systems.** Multiscale simulations of complex (molecular) systems models rely on accurate but expensive techniques on each scale that transfer information between them. This position will explore and develop recent techniques to replace these by much faster trained deep networks.	A& SC	DD, SL	
5	**TT Algorithmic Techniques for Discrete Optimization.** Algorithm design for discrete optimization problems is rapidly influenced by Data Science and Machine Learning. This position will focus on theoretical properties of such methods relevant for discrete optimization, as well as their application in various sectors such as Health and Smart Mobility.	DM	O&UQ	
6	**TT Statistics and Random Networks.** Expand the fundamental expertise on applications of network models to real-world data, by parameter estimation, as well as goodness of fit and ML techniques to validate the random network models. The aim is to use the available expertise on random graph theory with statistical methodology on network data.	S	SL,Nw	
7	**Network Data Lab Engineer.** This engineer will help build data lab facilities for the researchers to provide easy access to data and facilitate the application of their analytics to real network societal issues (e.g. social networks, health, and food data).	S	SL,Nw	

Below we give an overview over *all twelve positions* that we plan to fill, both those for which we request *sectorplan* funding (in **boldface**) and those that we finance through repositioning retirements. Abbreviations: *zwaartepunten* Analysis and Scientific Computing (A&SC), Discrete Mathematics (DM), and Stochastics (S), and national focus areas Dynamic Data (DD), Networks (Nw), Optimization and Uncertainty Quantification (O&UQ), and Statistical Learning (SL).

Chairs and positions	ZP	Nat. focus areas
Strengthening of the existing chair *Combinatorial Optimization:*		
TT Robust Optimization.	DM	O&UQ
TT Algorithmic Techniques for Discrete Optimization.	DM	O&UQ
TT Computational Integer Programming.	DM	O&UQ
New chair in *Statistics for Networks:*		
Professor in Statistics for Networks.	S	SL,Nw
TT Statistics and Random Networks.	S	SL,Nw
Network Data Lab Engineer.	S	SL,Nw
TT Spatial-Temporal Statistics.	S	SL,Nw
TT Stochastic Network Optimization.	S	Nw, O&UQ
TT Bayesian Networks & Bioinformatics.	S	SL,Nw
New chair *Machine Learning in Computational Science:*		
Professor Machine Learning in Computational Science.	A& CS	DD, SL
TT ML-Enhanced Computational Modelling of Complex Systems.	A& SC	DD, SL
TT Data-Driven Complexity Reduction.	A& SC	DD, SL

9 Smart Parameters: goals and monitoring

9.1 Diversity

Mathematics in Eindhoven has a strong focus on diversity, both for the student population and for members of staff.

As for diversity in the **student population**, our activities are part of our general outreach activities. Gender is an essential focus: we organize and stimulate a range of such activities aimed at girls and women at primary school, high school, university, and beyond, and our own female researchers play a central role in these activities as role models. Several researchers are VHTO volunteers and regularly visit high schools to encourage girls to consider a career in Mathematics. A PhD student was selected for the "Faces of Science" project of KNAW and maintains a blog on the communication of mathematics to high school pupils. Another PhD student is the local representative of the Dutch branch of the European Women in Mathematics network (EWM-NL). In addition, the president of EWM-NL, the national representative of the International Mathematical Union's Committee for Women in Mathematics, and the past president of the Women in Science Eindhoven network are among our staff. Several female researchers are members of WISE and EWM-NL. PhD students of the department also participate at "Science Battles" (http://sciencebattle.nl/), which are public "battles" between scientists, with the goal of making science approachable to a wider public. Several faculty members have authored books on the popularization and communication of mathematics. All communication material, such as leaflets, websites, videos etc., present a balanced gender image and information teams during open days are at least one-third female.

Cultural diversity in the student population is promoted in many ways. We have a departmental ambassadors programme to help advertise the department internationally. We have double-degree programs with Politecnico di Torino and Universität Stuttgart, and Erasmus bilateral agreements with a wide range of universities abroad; we have dedicated staff helping exchange students navigate the Dutch life, logistics, and application process. Since 2015, our MSc students are actively stimulated to spend part of their time abroad, and support is available to help them organize this.

For **members of staff**, the university-wide 2016 comprehensive policy on personnel management describes the full career path, starting with recruitment and hiring, and continuing through various phases of promotion. As a result of this policy interdepartmental committees have been created to connect and align the activities of hiring and promotion committees across the university and counteract implicit bias. Members of these interdepartmental committees participate in each selection committee.

We are confident about the *cultural* diversity of our staff: half of our staff members are from abroad, both English and Dutch are formal languages of the department, all meetings are conducted in English, and we teach nearly all courses in English. Our *gender* diversity, however, is unsatisfactory (currently 18%), and we have recently taken significant steps to improve this:

- Recruitment: All hiring already is preceded by an active search for female talent on the international market, through personal contacts and organizations such as EWM-NL, SheTalentbank.nl, and the Dutch Network of Women Professors (LNVH). In addition we have good experiences with enlisting the hiring agency Euflex to further widen the search. We also make use of non-standard advertising channels, such as social media; another example is an advert in March 2019 in a special issue of Die Zeit on 'Women in Science'. Since 2017 we require half of the candidates on shortlists to be female, and we aim to fill at least 50% of the new positions with female candidates. This will be implemented by setting up a 'mathematics-wide' hiring committee, which will consider the candidates that apply as a group. This will allow us to achieve the stated aim of 50% female appointments.
- Tenure-track phase: We formulate personalized tenure-track requirements that are tailor-made for the needs of the employees, incorporating generous allowances beyond Dutch legislative requirements around child birth, parental leave, and care duties. In order to combat the implicit biases in evaluations, we correct indicators for female personnel in selection committees. We have diversity officers both at departmental and university levels who engage in dialogues with target groups in order to help formulate gender-balanced and diverse policies. Our policies are continuously updated to reflect the outcomes of this dialogue.
- Promotion: We allow for personal development plans at all levels (including professors) so as to increase transparency in promotions and eliminate implicit biases. These plans involve personalized criteria that take into consideration the time frame and talents of each employee, including potential parental leave.

For the positions described in this *sectorplan* we aim for at least 50% female appointments. This will increase the number of female permanent and tenure-track staff members by at least six, raising our female–staff percentage to an estimated 26%.

Table 4: Nulmeting en streefwaarden voor bemensing per discipline.

TU/e Mathematics	**Ambition 2024**
Permanent scientific staff (FTE, dd 31-12-2018)	45
Tenure trackers (in FTE)	9
Postdocs (FTE)	17
Women in permanent scientific staff (FTE)	10
Women in tenure track (FTE)	5
Women in postdoc position (FTE)	8
% Women in new sectorplan positions	$\geq$ 50%

TU/e Mathematics		**Ambition 2024**
Quality	Competitive grants	×
	Awards	
	Papers (FWCI; % in top 5% Journals)	
	Av. number of citations per paper	
	Other parameters	
Relevance	NWA grants in M€	
	Topsectoren grants in M€	
	Societal collaborations (narrative)	
	Number of patents	1/year
	Number of Start-ups / spin-offs	1/y resp. 1/y
	Industrial collaboration	1.5 M€/year
	Size 2nd and 3rd tier funding	2nd: 3,5 M€/y 3rd: 2 M€/y

Table 6: Education (including PhDs) per discipline

TU/e Mathematics	**Ambition 2024**
1st year Bachelor	140
% Women in 1st year Bachelor	35%
1st year Master	70
% Women in 1st year Master	30%
% 1st year Bachelor students graduated within 4 years	65%
% 1st year Master students graduated within 3 years	85%
Nr of PhD theses	18
% of PhD theses from women	30%
Nr of PDEng theses	0
% of PDEng theses from women	0%
The PDEng program in Mathematics has been discontinued.	

9.2 National role in society and science

To maximise the societal and scientific impact of our research, Mathematics in Eindhoven focuses on the following:

- Intra-TU/e collaboration: Mathematics is co-founder of the university-wide *Institute for Complex Molecular Systems* and the *Eindhoven Multiscale Institute*, and has collaborations with all of the other departments. Mathematics is actively involved in the three TU/e Strategic Areas on Energy, Smart Mobility and Health.
- Nationwide mathematical collaboration: With our sister institutes in Delft and Twente and our mathematics colleagues in Wageningen, we form the 4TU Applied Mathematics Institute (4TU.AMI). Research at the Centrum Wiskunde & Informatica (CWI) in Amsterdam shows strong similarities with ours. Longstanding collaborations exist, as reflected in the large number of former CWI researchers in our staff and ongoing joint research projects. Together with Computer Science we play a major role in the NWO Gravitation program NETWORKS. We actively participate in the Platform Wiskunde Nederland (PWN), the Dutch national organization for mathematics, and PWN director Wil Schilders is one of our staff members.
- National research programs: We are active in the NWA route *Energy Transition*, through NWO-TTW Perspective programs and PhD projects in the framework of the Shell-NWO program Computational Sciences for Energy Research.
- Industrial partnerships: In addition to collaborations with a wide range of industry partners, we aim to invest in strategic long-term partnerships with selected companies. The Impuls I & II TU/e-industry programs and our partnership with Signify on non-imaging optics have led to over fifteen PhD projects.
- Partnerships with national research institutes: We also have running collaborations with large technological institutes (Deltares, ECN, MARIN, NLR, NRG, TNO-NOMI) and with governmental institutes, ranging from CBS to Rijkswaterstaat.

9.3 International positioning and affiliations

We strive to further increase our funding from European programs, ranging from personal grant programs to project grants in cooperation with industries. We actively participate in the EuroTech Universities Alliance, a partnership of six universities of technology (Technical University of Denmark, École Polytechnique Fédérale de Lausanne, École Polytechnique, Technische Universität München, Technion and TU/e). On a personal level, excellent research collaborations exist with very many individual researchers worldwide, in both academia and industry. Many of our staff members play active roles in international mathematics societies and boards.

9.4 Relationship with teachers and teaching

Mathematics in Eindhoven maintains a wide range of contacts with local schools and teachers. We organise guest lessons on mathematical topics for high school students and hold practicals for *Wiskunde D* students. Through the network of teachers we have a strong contribution to continuing education; our most recent courses were organized jointly with TUD and UT, and focused on Analytic Geometry, Statistics, and Mathematical Thinking. Eindhoven is the organizational hub of the national Mathematical Olympiads, and each year several members of staff help train the pupils.

Eindhoven Mathematics will be joining the nationwide Dutch plans for both outreach and teacher training, which Platform Wiskundig Nederland is developing at this moment in collaboration with the *betadecanen*.

9.5 Contribution to Open Science

TU Eindhoven and Mathematics in Eindhoven both strongly promote open science. The *Repository TU/e* collects all publications of scientists, registers the conditions of access (open, closed, or timed) and makes them freely available through the TU/e Research Portal[1] when allowed. The TU/e library also contributes to the *OpenAIRE* project[2] that promotes open access and open data, increasing the visibility and accessibility of scientific output from TU/e. In addition, most researchers make their publications available via open-access preprint servers such as `arXiv`, the CASA report series, the EURANDOM preprint series, or the Cryptology ePrint Archive. Many implementations of cryptographic algorithms are shared through SUPERCOP[3], the Networking and Cryptography library[4] and lipqcrypto[5].

[1] `https://research.tue.nl/`
[2] `https://www.openaire.eu/mission-and-vision`
[3] `https://bench.cr.yp.to/supercop.html`
[4] `https://nacl.cr.yp.to/`
[5] `https://libpqcrypto.org/`

PHYSICS

6 TU/e: Applied Physics: 'Facultaire zwaartepunten'

In the *Sectorbeeld*, the discipline of physics has defined six *focusgebieden* nationwide:

1. Particle and gravitational physics
2. Quantum materials and technologies
3. Complex systems, soft matter & fluids
4. Physics of life & health
5. Energy & sustainability
6. Precision measurement & fabrication.

Our department has three *zwaartepunten*:

a. Fluids, Bio & Soft Matter (FLOW)
b. Plasmas & Beams (PLASMA)
c. Nano, Quantum and Photonics (QNANO)

Five of the national *focusgebieden* are nourished by the disciplinary strengths of our *zwaartepunten*. *focusgebied* 1 (Particle and gravitational physis) is not active in our department. *zwaartepunt* QNANO has close connections with *focusgebied* 2 and 5, *zwaartepunt* FLOW operates in 3–5, and *zwaartepunt* PLASMA operates in 2–6.

Two very prominent societal challenges of this moment are the energy transition and information technology. These challenges are also addressed by the TU/e strategy 2030: in the Cross Disciplinary Research themes (CRT's). Furthermore, they are prominently present in the National Science Agenda (NWA) and in the Topsectoren.

The energy transition is addressed by the national physics *focusgebied* 5 (Energy and sustainability), and it is part of the TU/e strategy 2030 in the CRT Renewable energy. This theme is well represented in the NWA route 'Energietransitie', and the Topsector 'Energie'. Furthermore, this *focusgebied* is characterized by strong connections to societal partners, and with groups at UU. Additionally, a strong synergy with the department of Electrical Engineering exists in the area of energy-saving information technologies: a dedicated Gravitation program 'Research Center for Integrated Nanophotonics' is active in this field (coordinated by the physics department). The DIFFER institute has moved to the TU/e campus in 2015. The main reason for this was the great potential for collaborations between DIFFER and TU/e in the field of energy research, with our department as a frontrunner. Significant cooperation exists already, and it will be fostered further by new cross-appointments and collaborative projects on energy research.

Information technology is addressed by the national *focusgebied* Quantum materials and technologies, and it is also part of the TU/e strategy 2030 in the CRT Complex high tech systems. In the NWA, the corresponding route is 'De quantum-nano-revolutie', and the corresponding Topsector is HTSM. It has a stronghold in emerging quantum technologies, particularly nanostructured materials for quantum devices and quantum simulators consisting of Rydberg atom clusters. These activities are the basis for long-standing collaborations with TUD and UvA and enjoy outstanding international visibility (e.g. for the work on Majorana fermions).

We have realized that there is a great potential for innovative cross-cutting research at the interface of complex fluids and soft (bio)matter. Therefore, well before the sectorbeelden were conceived, we already combined our efforts in these two subdisciplines in our *zwaartepunt* Fluids, bio and soft matter (FLOW). This entire *zwaartepunt* is part of the national *focusgebied* Complex systems, soft matter & fluids. The *zwaartepunt* profits from coordinated research efforts in NL (Burgers Centre, Softmatter.nl, etc.) and with UU in this area, but also the intertwining with actions in the departments of Mechanical Engineering, Chemistry and Mathematics. In particular, the presence of the Darcy Lab (together with Mechanical Engineering), the High Tech Systems Center (HTSC) and the TU/e Institute of Complex Molecular Systems (ICMS) fosters a strong embedding of this *focusgebied* in the TU/e ecosystem.

In the alliance UU-TU/e-UMCU one large joint program (on plasma medicine) has started recently. Already for a long time, in the area of soft matter physics and spintronics there are strong collaborations, including exchange of several part time professorships of staff in both directions. We will invest further in this alliance by establishing new joint efforts on the areas of soft matter physics, permeable media (Darcy Center), and (meta)photonics. The two institutes both invest in these areas, and are complementary: joint forces enable scientific breakthroughs in the relevant *focusgebieden*.

6.1 Zwaartepunt Fluids, Bio & Soft Matter (FLOW)

This *zwaartepunt* combines the PI's in fluid dynamics with the PI's in soft matter physics. Fluid dynamics has a long tradition in the department, and is very well connected to the other groups in NL in this area through the J.M. Burgers Center, the national research school for fluid dynamics. The combination with the soft matter activities has a great potential for innovative cross-cutting research at the interface of complex fluids and soft (bio)matter. Furthermore, the length scale that the cluster now operates in covers the whole world between (fluid) physics at the nanometer scale up to complex flows at geophysical scales. The work encompasses experimental work and theory/modeling in a good balance. This departmental *zwaartepunt* is integral part of the national *focusgebied* (3): Complex systems, soft matter & fluids, and it also touches the *focusgebieden* 4 and 5.

6.2 Zwaartepunt Plasmas & Beams (PLASMA)

This *zwaartepunt* covers all regimes of man made plasmas, from ultracold plasmas (millikelvins) via moderate temperature plasmas (several eV's) to fusion plasmas of millions of degrees. The work is characterized by strong connection to the research in the NWO institute DIFFER. The work encompasses experimental work and theory/modeling in a good balance. This departmental *zwaartepunt* is nationally unique in the Dutch landscape. The PI's are characterized by strong internal connections: two annual conferences are held every year, and many joint projects are operational. This *zwaartepunt* is strongly interdisciplinary, and is therefore active in all national *focusgebieden* except Particle & gravitational physics. The strategic choices that we put forward in this plan, however, concentrate on strengthening the core *discipline of plasma physics*.

6.3 Zwaartepunt Nano, Quantum and Photonics (QNANO)

This *zwaartepunt* consists of all PI's that are active in photonics, quantum physics, spintronics, material science, nanowires, organic semiconductors, 2D materials, etc. The common denominator within the *zwaartepunt* is the physics of nanomaterials and of their optical properties. The area of photonics is a nationally unique stronghold, which is currently increasing its strength in a synergy with the device- and system-oriented research in corresponding groups within the TU/e EE department. This departmental *zwaartepunt* is mainly active in the national *focusgebied* Energy & sustainability and Quantum materials & technologies.

7 Characteristics of the 'zwaartepunten' for which funding is requested

TU/e, Applied Physics
FLOW
Scientific content: This *zwaartepunt* was created near the end of 2018, by combining the existing fluid dynamics cluster with two groups that are active in the area of soft matter physics. The research in this *zwaartepunt* encompasses theoretical and experimental work and development of advanced computational tools. The fluid mechanics groups address topics as transport and phase changes in complex permeable media, complex fluids and flows, and specifically turbulence, environmental fluid mechanics, multiphase flows and active matter, and micro- and nanohydrodynamics. The soft (bio)matter groups address topics as theoretical and simulation approaches of soft and biological materials in the context of the mechanobiology of cells and tissues, as well as functional soft materials, and biosensing with single-molecule resolution using nanoparticles. Shared interests between the individual groups are found in the themes rheology of active biofluids, transport in multicomponent systems, and particle biosensors. The fundamental knowledge on responsive permeable media, reactive solids and soft (bio)matter together with those of transport processes in complex fluids and flows will be used to strengthen the foundation at the interface of the classical fields of fluid dynamics and soft matter for, e.g., energy applications and active matter physics. This is a strongly growing field internationally with many exciting innovative developments. The groups have a strong internal coherence, are nationally well-positioned and unique, and provide the necessary complementary expertises in this s *zwaartepunt* to tackle the challenges for the future by strengthening the fundaments of complex systems, soft matter and fluids. It will strongly take advantage of the unique laboratory facilities (Darcy Lab) and TU/e IRES initiatives. The zwaartepunt is developing links with the TU/e Center for Computational Energy Research (CCER) and the TU/e Institute for Complex Molecular Systems (ICMS). The energy related work is carried out in collaboration with DIFFER (energy storage).
Quality and Impact: In the last departmental research assessment (Onderzoeksvisitatie) of Dec. 2018, the review committee mentioned: "The research quality of the cluster is uniformly outstanding, as evidenced by numerous high-profile publications in both disciplinary (e.g., Physical Review Letters, Nano Letters, Applied Energy) and broader journals (e.g., Nature, PNAS, Langmuir), as well as by citation data. The quality of the cluster's faculty is further highlighted by numerous prizes, awards and research society fellowships, as well as journal editorships." The cluster has one KNAW member, and several full professors have obtained personal grants like VICI. Also other personal grants like VENI, VIDI and ERC have been acquired. The professors active in this *zwaartepunt* have or had leadership roles in large national and European programs. The *zwaartepunt* is currently active in the Topsectors Energie, Water, Chemie, LSH, AgroFood and HTSM through many running projects including TKI. NWA routes covered are, for example, 'Energietransitie', 'Materialen', 'Blauwe route', 'Personalized Medicine' en 'Bouwstenen'.
Master tracks: Master program Applied Physics (Croho 60436, track FLOW)
Size and intended expansion of the permanent scientific staff: This *zwaartepunt* currently has 7 full professors, 4 associate professors, and 9 assistant professors. We seek extension with 1 full professor, and 2 assistant professors. The full professor position will strengthen the national *focusgebied* Energy and Sustainability by deepening the foundations in the areas of responsive matter and energy storage in connection with DIFFER. The two assistant professor positions are aimed to strengthen the foundation in the areas of fluids and soft matter, where strongest growth is expected: the interface of (complex) fluids and soft (bio)matter. It will strongly contribute to the national *focusgebied* Complex systems, soft matter & fluids.

TU/e, Applied Physics

PLASMA

Scientific content: This departmental *zwaartepunt* is nationally unique in the Dutch landscape: at no other Dutch university a sizeable plasma physics cluster is present. It covers 4 groups that together cover all regimes of man made plasmas, from ultracold plasmas (millikelvins) via moderate temperature plasmas (several eV's) to fusion plasmas of millions of degrees. Applications cover an extremely wide range: from ultra bright beams of electrons and ions via semiconductor processing and medical applications to nuclear fusion. It is the discipline of plasma physics that connects all these regimes and applications. Together, the groups study the interaction of charged species, electrical fields and photons with gaseous, liquid, solid and soft matter. The scientific focus of plasma physics worldwide used to be on descriptions of collective phenomena in the bulk of the plasma. In Eindhoven, we have shifted the attention to aspects that are pertinent to the area where the plasma bounds a wall, and to phenomena that are induced by the interaction of the plasma with photon fields. Inside the bulk of the plasma, the focus is no longer on collective phenomena, but on elementary processes on the atomic and molecular scale. It is the study of these aspects that can bring plasma physics a step forward: further on its way to provide solutions for societal needs like the energy transition and information technology.
The work is characterized by strong connection to the research in the NWO institute DIFFER, and encompasses experimental work and theory/modeling in a good balance. The groups are characterized by strong internal coherence: two annual conferences are held every year, and many joint projects are operational. This departmental *zwaartepunt* is strongly interdisciplinary, and is therefore active in all national focusgebieden except Particle & gravitational physics. The strategic choices that we put forward in this plan, however, concentrate on *strengthening the core discipline of plasma physics*, while still fostering the dominant national focusgebieden of Energy & Sustainability and Quantum Materials & Technologies.

Quality and Impact: In the last departmental research assessment (Onderzoeksvisitatie) of Dec. 2018, the review committee mentioned: 'The TU/e Applied Physics department is clearly a world reference in the field of plasma physics, with a strong international profile. The overall Non-Thermal Plasma research is highly multidisciplinary and of very high quality. The number of publications, their quality, and their impact are excellent. Besides high-level fundamental aspects, numerous applications are explored which have very high societal impact. ... The mix of theory and experimental capabilities is an important strength that underpins a range of frontier, basic science research – in areas such as ultra-cold atoms, quantum gases and plasmas – with high impact in the development of quantum simulators. ... The fusion research goes beyond plasmas, into the important area of materials for extreme environments, including the role of liquid metals.'
All group leaders have acquired a personal grant (Pionier, VICI). The zwaartepunt is currently active in the Topsectors Energie and HTSM through many running TKI projects. NWA routes covered are 'Energietransitie', 'De quantum-nano revolutie', and 'Meten en detecteren'

Master tracks:
- Master program Applied Physics (Croho 60436, track PLASMA)
- Master program Science and Technology of Nuclear Fusion (Croho 66904)

Size and intended expansion of the permanent scientific staff: The *zwaartepunt* currently has 5 full professors, 7 associate professors, and 7 assistant professors. We seek extension with 1 full professor, and 2 assistant professors. The full professor and one assistant professor will strengthen the national *focusgebied* Energy and Sustainability. The other assistant professor will strengthen the national *focusgebied* Quantum Materials & Technologies.
With DIFFER, cross-over appointments will be created: DIFFER personnel getting a 0.2 or 0.4 fte appointment at TU/e-Physics, and vice versa. These cross-over appointments will not have financial consequences for the *sectorplan* budget.

TU/e, Applied Physics

QNANO

Scientific content: This *zwaartepunt* has a strong focus and unique national position in the physics of nanomaterials and nanostructures. It combines a strong expertise and state-of-the-art facilities in the growth and deposition of semiconductor, dielectric and metal films, with nm-scale control capabilities, with advanced characterization facilities, ranging from atomic-scale imaging to ultrafast and single-photon optical spectroscopy. The scientific focus lies in the investigation of the electronic, magnetic, and optical properties of novel materials, and the control of their functionality via their composition and structure at the nanoscale – down to the single atomic layer. Besides the strong fundamental nature of this research, testified by a continuous level of high-impact publication output (including Nature, Science and the like), all groups are actively exploring the possible application of these materials in the context of renewable energy (new materials for solar cells), of energy-saving information technologies (photonics, spintronics) and of quantum information processing (quantum simulation and quantum computing). As the large majority of these applications are related to the optical properties of nanomaterials, photonics plays a key role in the cluster and has, together with the device- and system-oriented photonics research within the TU/e EE department, a prominent position at the national and international level. The cluster is mainly active in the national focusgebied Energy & sustainability and Quantum materials & technologies.

Quality and Impact: In the last departmental research assessment (Onderzoeksvisitatie) of Dec. 2018, the review committee mentioned: 'The QNANO disciplinary cluster comprises four very strong research groups with scientific foci that span the range from fundamental studies of novel physical, photonic, electronic and magnetic properties of nano- and molecular-scale materials to applied nanoscience and novel devices. ... The evaluation committee found the scientific themes addressed in this cluster to be of a very high scientific quality, with some aspects ranked as being very good and others clearly having a world leading character.'
The excellent quality of the cluster is further evidenced in the exceptionally high number of top-level personal grants: One Spinoza prize, one ERC advanced and one ERC consolidator, and six VICI grants. The researchers active in the cluster have or have had coordinating roles in large national and European programs, ranging from NWO-physics programs, Industrial Partnership Programs (IPPs), EU-FP6 and Horizon2020 projects, and the NWO Gravitation program 'Integrated Nanophotonics'.
The industrial and societal relevance of the cluster's research is testified by its strong collaborations with industry (including among others Microsoft for quantum computing, Philips for lighting, IBM for silicon-based light sources) and wide participation in European projects (including coordination). It brings a key contribution to the TU/e's Institute for Photonic Integration and to the Center for Quantum Materials and Technology Eindhoven (QT/e). The groups are also active within the NWA routes 'De Quantum/nano-revolutie', 'Energietransitie' and 'Meten en detecteren' and have several projects running within the Topsector HTSM and Energy.

Master tracks:
- Master program Applied Physics (Croho 60436, track NANO)

Size and intended expansion of the permanent scientific staff: The *zwaartepunt* currently has 8 full professors, 5 associate professors, and 3 assistant professors. We aim for expansion with 3 assistant professors. The corresponding research themes are defined with the aim of strengthening the foundation in the areas which experience the strongest growth in the cluster, namely metaphotonics and nanomaterials for Energy (national *focusgebied* Energy and Sustainability), and nanomaterials for quantum technology (national *focusgebied* Quantum Materials & Technologies).

8 Requested positions

We have chosen to align the priorities for strengthening of the department along the lines of the national *focusgebieden*. In the *sectorbeeld* we have distributed 4 points over the 6 *focusgebieden*, and we have now decided to strengthen only 3 of them. Our first priority is with Energy & sustainability, followed by Quantum materials & technologies and Complex systems, soft matter & fluids.

The national *focusgebied Energy and Sustainability* will be strengthened with 5 new positions.

- The first position is a full professor in the FLOW zwaartepunt in the field: *Responsive Permeable Media: Paradigm for the next-generation energy storage*. Multiscale (nano-macro) heat-mass transport in responsive permeable media plays a pivotal role in energy storage, direct air capture of CO_2 and separation processes. This position will focus on the responsivity of such materials involving complex transition states and adsorption/desorption processes.
- The second position is an assistant professor position entitled *Metaphotonics* in the QNANO *zwaartepunt* and targets the investigation of novel approaches to reduce the energy footprint of information technologies. They are based on nanostructured and composite materials made of ultrathin layers exhibiting novel (magneto-)optical properties. This opens new avenues to light control, switching and routing on a chip, potentially much more energy-efficient than present solutions.
- The third position is a full professor called *Plasma surface interaction*, and is situated in the PLASMA *zwaartepunt*. This position is aimed at bridging the gap between the several plasma regimes in the *zwaartepunt*. Existing strengths in the low temperature plasma physics groups will be combined with the knowledge in the Fusion group and DIFFER to cover new grounds: investigate interaction mechanisms both experimentally and theoretically. This will foster the valorization opportunities in the energy arena in many areas (fusion, CO_2, solar, etc.)
- The fourth position is an assistant professor in *Nanomaterials for Energy*. New metastable materials have emerged by manipulation of crystal growth at the nanoscale. As an example, new crystal phases of matter show fascinating photonic and phononic properties. The aim is to explore these materials in the field of energy, such as e.g. photovoltaics, thermoelectrics, and thermophotovoltaics.
- The fifth position is an assistant professor in *Plasma Physics*. Theories and models in plasma physics are characterized by the dominant important of source terms. What we target here is an approach that starts from elementary processes, and makes the connection from these processes to the more global understanding efforts. Fundamental data on elementary processes is scarce, but modern theories and dedicated experiments can lead the way. Focus will be on processes related to the energy transition, e.g. CO_2 harvesting.

The national *focusgebied Complex systems, soft matter and Fluids* will be strengthened with 2 new positions.

- The first position is an assistant professor in *Biomatter in context: Flow, mechanics and molecules*. The behavior of bio-entities like cells, bacteria, and viruses is informed by their fluidic environment, both through mechanical (visco-elastic, fluid dynamical) and molecular interactions (adhesive structures, molecular cues). The position will bridge existing strengths in molecular sensing, soft biomatter and micro- and nanofluidics, to establish an integrated experimental-theoretical research effort to understand how molecular and (fluid) mechanical interactions between biomatter and their physical environment can be leveraged for analysis and control of soft matter.
- The second position is an assistant professor in *Complexity in action: Multiscale physics of living and social systems*. Active matter physics, describing the (collective) motion of self-propelling agents, is increasingly employed to understand out-of-equilibrium self-organization in biological systems like bacteria populations, algae and biofilms, and large-scale natural systems like flocks of birds, fish schools, human crowds and traffic. Understanding and ultimately controlling such phenomena demands first of all a proper physical description of active matter, complemented with application of machine learning tools and stochastic approaches.

The national *focusgebied Quantum materials & technologies* will be strengthened with 2 new positions.

- The first position is situated in the QNANO *zwaartepunt* and is called *Electronic Quantum Materials*. Up till now materials are classified regarding their properties as a metal, semiconductor or insulator. Recently, topology has emerged as a new organizing principle. Building upon our world-leading expertise on the synthesis of new electronic nanomaterials (nanowires, 2D, hybrids, topological (crystalline) insulators, magnetic), we propose an experimental research effort to investigate emerging quantum phases.
- The second position is situated in the PLASMA *zwaartepunt* and is called *Ultracold plasmas*. Ultracold plasmas are created when an ultracold gas is ionized by a tailored laser pulse. These plasmas are the basis of the present work on strongly-interacting quantum gases, Rydberg atom clusters and

quantum simulators, but they also underpin the present work on ultra-bright beams of electrons and ions. An experimental position is envisaged that strengthens the combined foundations of plasma physics and quantum technology.

Table 3: Overzicht investeringsplannen per discipline. Abbreviations: ES: Energy & Sustainability; QM: Quantum materials & technologies; CS: Complex systems, soft matter & fluids.

TU/e: Applied Physics: Requested Positions			
P	Individual positions and subsequent research themes	ZP	
1	Responsive Permeable Media: Paradigm for the next-generation energy storage. Full prof. theory. *Extra start-up package from CRT Energy*.	ES	
2	Metaphotonics. Assistant prof. exp. *Extra start-up package from CRT Materials and CRT High Tech Systems.*.	ES	
3	Plasma surface interaction. Full prof. theory.	ES	
4	Electronic Quantum Materials. Assistant prof. exp. *Extra start-up package from CRT Materials*.	QM	
5	Biomatter in context: Flow, mechanics and molecules. Assistant prof. exp. *Extra start-up package from CRT Health*.	CS	
6	Nanomaterials for Energy. Assistant prof. exp. *Extra start-up package from CRT Energy*.	ES	
7	Ultracold plasmas. Assistant prof. exp. *Extra start-up package from CRT High Tech Systems*.	QM	
8	Complexity in action: Multiscale physics of living and social systems. Assistant prof. theory. *Extra start-up package from CRT High Tech Systems*.	CS	
9	Plasma Physics. Assistant prof. theory. *Extra start-up package from CRT Energy*.	ES	

9 Smart Parameters: goals and monitoring

9.1 Diversity in staff

At this moment, the department has 55 payroll staff members, 8 of them female. Among our PhD students 35% is female. Among the 14 tenure trackers who started in the department in the last 6 years, 50% was female. As we will reserve more than 50% of the granted *sectorplan* positions for female candidates, our number of female staff members in 2020 will have grown to around 20%. This is in comfortable agreement with the '20% in 2020' statement in the women's charter 'Talent to the top' issued by FOM in 2010. But we aim to go beyond that. Countries like France demonstrate that a fraction of 30% female participation in physics staff is self-sustaining. If we fill 35% of the vacancies arising from the retirement of staff in the period 2022-2028 with female candidates, that goal of a self-sustaining percentage of 30% female staff is indeed achievable by 2028. The actions that we will take are:

- **All of our 9 *sectorplan* positions** will be enrolled in the Irène Curie Fellowship program. All positions are open to female candidates only until mid November 2019.
- One position will be added to the recruiting process. That position is not limited to the 3 *focusgebieden* we are strengthening, but will have a scope that covers all of the 5 department's active *focusgebieden*. The position is only available for female candidates. If the profile of the final candidate does not fit the profile of any of the positions arising from this *sectorplan*, then the department will cover the expenses of that position from its own resources.
- The PI's in our department are scanning actively for female and non-western immigration talent through their networks. Every 6 weeks, during the regular meeting of the department board with the capacity group chairs, the chairs will be asked to report on the actions taken and the progress obtained. At the moment, a promising line-up of female candidates on all levels is already forming.
- Compatibility with the profiles of the *sectorplan* positions is only sought after in a broad sense: the candidates should fit into a local *zwaartepunt* of TU/e physics, and it should also fit in one of the national *focusgebieden* of physics that are worked on in Eindhoven.

- Dual career opportunities will have the full attention of the department board. The TU/e Dual Career Opportunity program ESI of TU/e and Brainport will assist in this aspect.
- In the hiring process, male candidates will only be appointed after at least 50% of the total number of available positions (including the 'joker' position of the second bullet) is taken by female candidates. This goes beyond the advice of PAN (Platform Academische Natuurkunde).
- At this moment, a mentoring program is being set up in the department that stimulates young academic staff in their career development. When the diversity balance is improved from the bottom up, this program will ensure that over the years this balance is gradually propagated over all ranks.

9.2 Diversity in students

The department holds regular meetings with several generations of female alumni. These generations encompass the period from the early eighties to present time. One representative is selected per half decade. The question asked to these alumni was how the environment of the department can be improved to be attractive to potential female students. Their advice was sometimes surprising. Summarising their input was: do not take any special actions for girls, but create an atmosphere that is open and diverse (Create a more informal atmosphere , laugh more, make sure there is no implicit gender bias in communication) Of course, visibility of female role models is also very important.

For this reason, the department focuses on increasing the fraction of female staff to a self-sustaining level of 30% in 2028, is installing female role models, and maintains low boundaries and fosters informality between students and staff.

From the academic year 2017, the curriculum of the department is fully in English, both for BSc and MSc. The fraction of international students has gone up steadily since then, from almost non-existent before 2017 to 15% in the academic year 2018-2019. The change in atmosphere is clearly noticeable. When students cooperate in small groups of 6 students like in DBL-courses, most of these groups speak English among each other. The international students are clearly given a warm welcome by the Dutch students. This attitude among the students enables a further development among students towards more natural diversity.

9.3 Dissemination and valorization

The Department is putting a systematic effort in valorization. One of the steps that is taken is that four valorization themes have been adopted:

- Smart materials and processes
- Renewable energy
- High tech systems
- Engineering health

It is no coincidence that these four themes are also present in the six Cross-Disciplinary Research Themes (CRT's) that have been installed within TU/e. Three of them also represent today's big societal challenges. They also are four themes that offer opportunities for connecting to and collaborations with the High-Tech industrial ecosystem around us consisting of companies like ASML, Philips, Océ, NXP, FEI and VDL, and hospitals like MMC, CZE and Kempenhaeghe.

Organizations like TNO and ECN are linked to the department by cross-appointments (part time professorships), as are some of the companies listed above. Collaborations also exist with HBO-institutes like the HAS and various Fontys departments, as well as with DIFFER, AMOLF, and the Westerdijk Institute.

The department actively seeks exposure of its research in events where (very) many people are reached. Examples are the SensUS competition, and the GLOW festival that attracts 750.000 visitors to the TU/e campus. Appealing research experiments are then demonstrated before the public in a layman's way, aiming at future students and their parents.

In the last four years, five new start-up companies were founded by the department. These are also taking their role in the dissemination of results of the department's research in industry and society.

9.4 Open science

TU Eindhoven and Physics in Eindhoven both strongly promote open science. The Repository TU/e collects all publications of scientists, registers the conditions of access (open, closed, or timed) and makes them freely available through the TU/e Research Portal when allowed. The TU/e library also contributes to the OpenAIRE project that promotes open access and open data, increasing the visibility and accessibility of scientific output from TU/e. In addition, most researchers make their publications available via open-access preprint servers such as arXiv.

Table 4: Nulmeting en streefwaarden voor bemensing per discipline.

TU/e Physics	**Ambition**
Permanent scientific staff (FTE, dd 31-12-2018)	56
Tenure trackers (in FTE)	9
Postdocs (FTE)	37
Women in scientific staff (FTE)	12
Women in tenure track (FTE)	4
Women in postdoc position (FTE)	7
% Women in new sectorplan positions	≥50%

Table 5: Te monitoren indicatoren mbt quality and relevance, per discipline.

TU/e Physics		**Ambition**
Quality	Competitive grants	×
	Awards	
	Papers (FWCI; % in top 5% Journals)	
	Av. number of citations per paper	
	Other parameters	
Relevance	NWA grants in M€	
	Topsectoren grants in M€	1,5 M€/year
	Societal collaborations (narrative)	
	Number of patents	6/year
	Number of Start-ups / spin-offs	1/y resp. 1/y
	Industrial collaboration	6 M€/year
	Size 2nd and 3rd tier funding	2nd: 8 M€/y 3rd: 8 M€/y

Table 6: Education (including PhDs) per discipline

TU/e Physics	**Ambition**
1st year Bachelor	230
% Women in 1st year Bachelor	20%
1st year Master	160
% Women in 1st year Master	15%
% 1st year Bachelor students graduated within 4 years	70%
% 1st year Master students graduated within 3 years	70%
Nr of PhD theses	42
% of PhD theses from women	40%
Nr of PDEng theses	20
% of PDEng theses from women	50%

CHEMISTRY

6 TU/e: Chemistry: 'Facultaire zwaartepunten'

Research and education in the Chemistry discipline at TU/e is internationally reputed and covers sustainable process technology, advanced materials and complex molecular systems as the key research areas. The *sectorplan focusgebieden Sustainable Process Technology* and *Materials Chemistry & Functional Materials* are embedded in the Department of Chemical Engineering and Chemistry (CE&C). The *focusgebied Complex Molecular Systems* is covered by both the departments of Biomedical Engineering (BMT) and CE&C through shared professorships and it is institutionalized in the renowned Institute for Complex Molecular Systems in which also other TU/e departments participate.

In these *focusgebieden*, TU/e Chemistry clearly maintains an excellent national and international position in e.g. supramolecular organic chemistry, materials chemistry, process engineering and catalysis, evident from the participation in 3 national Gravitation programs, namely Functional Molecular Systems (FMS), Multiscale Catalytic Energy Conversion (MCEC), Materials-Driven Regeneration (MDR), many personal grants (> 10 VI, > 10 ERC), the endowment of senior PI's (KNAW memberships etc.) and (inter)national awards (3x Spinoza, Nagoya medal etc.). More than half of the research budget comes from 3rd tier funding sources. A total of 9 PIs is involved as elected members in the ARC Chemical Building Blocks Consortium. In addition to this, the applied side of the research is covered by a strong portfolio of bilateral and public-private partnership projects together with private partners.

The research within the *focusgebied Sustainable Process Technology* covers the spectrum of chemical engineering sciences, with main activities in reactor and separation technology, process intensification, and heterogeneous catalysis. The multiscale approach positions the cluster at the cutting edge of academic research while retaining a high standard of industrial innovation. The research groups collaborate intensively with the chemical industry to ensure the sustainability of chemical processes by increasing their energy and feedstock efficiency, as well as cooperating in the development of novel chemical and physical operating windows. The core disciplines of this cluster are multiscale multi-phase flow, transport phenomena, integrated and intensified reactors, catalysis and membrane separations. In total, 3 positions are requested to strengthen this *focusgebied* in line with the major societal challenges concerning a sustainable chemical industry and the energy transition. These challenges are strongly represented in the various agendas of the NWA (*Energy Transition, Circular Economy*), the Topsectors *Chemistry and Energy* and the mission-driven innovation policy concerning *climate and energy transition*. The requested positions are aligned between the chemical engineering departments of TU/e, TUD and UT. The research in the national *focusgebied* catalysis is strongly coordinated in the strategic TU/e-UU alliance focusing on renewable energy. TU/e has substantially invested in catalysis together with Utrecht University within the framework of the Gravitation program Multiscale Catalytic Energy Conversion.

Within *Materials Chemistry & Functional Materials* the focus is on the design and synthesis of novel molecules, macro- and supramolecular assemblies, and functional materials with a wide range of applications in the fields of energy, health, and sustainability. Researchers in this cluster aim to understand how molecular features are translated over different length scales in macroscopic material properties and functional performance. The research approach comprises the following key elements: new supramolecular concepts in organic and polymer chemistry, organic and polymer materials for optical, electronic and responsive devices, interface and physical chemistry of polymer materials, bio-inspired and multiscale materials. Within the field of materials chemistry, 3 positions are foreseen that will strengthen the research on energy conversion materials, circular polymer materials and supramolecular materials chemistry. These positions logically translate the fundamental insights obtained in the Gravitation programs FMS and MCEC into the development of materials and devices that solve societal challenges around sustainability and energy. Targeting applications in energy, health and adaptive materials also strengthens the interactions between the three TU/e chemistry *focusgebieden*. At the national level these positions are coordinated via the committee *Materials – Made in Holland*, which is also an NWA route. These activities also fit within the NWA routes *Energy Transition and Circular Economy.*

The overarching objective of the *focusgebied Complex Molecular Systems* is to develop a scientific base of how molecular interactions lead to complex behavior at different length and time scales. Understanding and modulating complexity is, on the one hand, key for the development of a next generation of adaptive molecular materials for soft robotics and energy materials research. On the other hand, a systems approach in chemical biology and (nano)materials research is mandatory for the advance of regenerative medicine and nanomedicine. A unique aspect of this activity is the use of a multidisciplinary systems approach, bringing together experimentalists and theoreticians who design, execute and analyze molecular systems with state of the art 4D (spatiotemporal) characterization techniques. Within this *focusgebied*, 2 positions are requested, namely computational modeling of complex molecular systems and immunomodulatory nanomaterials. The first position is crucial to predict how designer molecular building blocks will assemble into predefined structures. The second position makes it possi-

ble to translate fundamental knowledge into practical health applications. Both positions are aligned via the Gravitation program FMS. The computational position is highly complementary to existing knowledge, and other proposed positions on non-equilibrium systems. The second position furthermore fits very well in the TU/e-Utrecht alliance, in which nanomedicine has been selected as one of the investment areas. The research in this *focusgebied* links directly to the national *zwaartepunt* with the same name and its excellence is underpinned by the involvement in two Gravitation programs, namely MDR and FMS. The activities fit very well within the NWA routes *Materials – Made in Holland* and *Regenerative Medicine*.

7 Characteristics of the 'zwaartepunten' for which funding is requested

TU/e, Chemistry

Sustainable Process Technology

Scientific content: The research within this *focusgebied* covers the field of chemical engineering sciences, ranging from fundamental scientific understanding to targeted engineering applications. This approach positions the cluster at the cutting edge of academic research while retaining a high standard of industrial innovation. The major research areas in this cluster are reactor and separation technology, process intensification, and heterogeneous catalysis. Combining these elements across relevant length scales often leads to novel or improved reactor, separation, and process technologies and concepts.

Prof. Schouten, Prof. Gallucci, Prof. Van Sint Annaland, dr. Van der Schaaf, dr. Noel, dr. Groot and dr. Neira d'Angelo are active in the theme Sustainable Process Engineering, bringing together expertise in chemical reactor design, process intensification, renewables conversion and flow chemistry. Intensive collaboration between TU/e and UT process technology and TU/e and UU catalysis groups form the core of the gravitation program Multiscale Catalytic Energy Conversion and focus on establishing a multiscale modeling base in chemical processes. It has led to a new activity in mesoscale modeling (dr. Filot, tenured since 2018) linking quantum-chemical modeling of catalytic events (Prof. Hensen) to multiphase flow modeling (Prof. Kuipers). Prof. Nijmeijer succeeded Prof. Kroon in 2016 as the chair Membrane Materials and Processes, a position funded in the first *sectorplan* budget. This activity has been strengthened in 2019 with a tenure-track assistant professor dr. Forner-Cuenca (electrochemical membranes). In the field of catalysis, the TU/e-UU alliance has led to appointments of dr. Hofmann in solar fuels catalysis (2014) and dr. Figueiredo in inorganic electrochemistry (2019). Together, the new junior staff develop a chain of knowledge in the area of chemical energy storage (Forner-Cuenca-Hofmann-Groot-Figueiredo), complementary to the central theme of sustainable chemical industry.

Quality and Impact:
- ERC Advanced Grants, ERC PoF Grants, Veni/Vidi/Vici Grants, Start-Up/Top Grants
- DECHEMA prize 2017 (Noel), Academic Society Award 2018 (Nijmeijer)
- Gravitation program Multiscale Catalytic Energy Conversion (Hensen, Kuipers)
- Strong involvement ARC Chemical Building Blocks Consortium (Hensen, Kuipers)
- Many collaborations in EU H2020 programs, also as coordinator
- 2nd tier funding: ~3.3 M€/year; 3rd tier funding: 5.2 M€/year (2018 data)
- 1,071 publications, 16,868 citations, FWCI: 1.7, fraction top-10% journals: 0.68, international collaboration: 44% (2013->2018, SciVal)
- ~20 doctoral degrees per year
- Strong involvement in agenda-setting and road-mapping e.g. national schools like NIOK, ISPT, 'sectorraden' and 'werkgemeenschapscommissies'
- Founding father in Chemelot InSciTe biobased piloting program
- Patents in the domain of reactor engineering, start-ups such as FlowID and Vertoro

Master tracks:
- Chemical Engineering (CROHO 21PG-60437)
- Specialization Chemical and Process Technology
- Accredited by the Institute of Chemical Engineers (latest 2018 granted for 5 years)

Size and intended expansion of the permanent scientific staff (31-12-2018):
- Size staff: 20
- Requested expansion: 3

The total permanent staff of the cluster is 20 (in fte: 6.7 full-time professors, 3.0 associate professors, 8.3 assistant professors, 2 part-time professors). The cluster employs 20 postdoctoral research fellows and 101 PhD students. The request for expansion concerns 1 full time professor and 1 tenure-track position.

TU/e, Chemistry

Materials Chemistry & Functional Materials

Scientific content: This cluster focuses on the design and synthesis of novel molecules, macro- and supramolecular assemblies, and functional materials with a wide range of applications in the fields of energy, health, and sustainability. Researchers in this cluster investigate the relation between the molecular organization, the structure of advanced materials, such as polymers and multi-materials, and their functional performance. The focus is on the control of chemistry, structure and morphology as well as interfacial phenomena. The research approach comprises the following key elements: new supramolecular concepts in organic and polymer chemistry, and materials science, organic and polymer materials for optical, electronic and responsive devices, interface and physical chemistry of polymer materials, bio-inspired and multi-scale materials.

In recent years, Prof. Nico Sommerdijk has been appointed as the chair Bio-inspired and Multiscale Materials (2014), Prof. Remco Tuinier as the chair physical chemistry (2015), Prof. Jan van Hest as the chair bio-organic chemistry (2016; 50%) and Prof. Ilja Voets as the chair Soft Matter (2018; 50%). Prof. Voets' initial appointment was supported by the first *sectorplan*. The cluster is aligned via the ARC CBBC, especially via research on coating technology and energy materials. The polymer science activities are organized nationally via the roadmap Materials in Holland. Via the Gravitation program FMS, the universities of Groningen, Nijmegen and Eindhoven have integrated their research in supramolecular and macro-organic chemistry.

Quality and Impact:

- Several ERC Grants, ERC PoF Grants, Veni/Vidi/Vici Grants, Top Grants a.o. 2 running ERC Ad-vanced Grants (Janssen, Sommerdijk)
- 2 KNAW members, 2 Spinoza (Meijer, Janssen), Aspasia 2017 (Voets)
- Prestigious awards (Nagoya medal, Chirality medal)
- Gravitation program Functional Molecular Systems
- A total of 7 PIs involved in ARC Chemical Building Blocks Consortium
- Several collaborations in EU H2020 programs including as coordinator
- 855 publications, 18,536 citations, FWCI: 2.1, fraction top-10% journals: 0.78, international col-laboration: 47% (2013->2018, SciVal)
- ~18 doctoral degrees per year
- Number of start-ups: 2 per year; Gouden Kiem Award in 2016, 2017, 2018.

Master tracks:

- Chemical Engineering (CROHO 21PG-60437)
- Specialization Molecular Systems and Materials Chemistry
- Awarded the Euromaster label (latest 2018 granted for 5 years)

Size and intended expansion of the permanent scientific staff (31-12-2018):

- Size staff: 20
- Requested expansion: 3

The total permanent staff of the cluster is 20 (in fte: 7.9 full-time professors, 3.8 associate professors, 4.9 assistant professors, 2 part-time professors). The cluster employs 32 postdoctoral research fellows and 60 PhD students (2018 numbers). The request for expansion concerns 2 full time professors and 1 tenure-track position.

TU/e, Chemistry

Complex Molecular Systems

Scientific content: This cluster focuses on a fundamental understanding how molecular interactions lead to complex behavior in biological systems at different time and length scales. In order to obtain this improved insight, a multidisciplinary systems approach is followed, bringing together experimentalists and theoreticians who design, execute and analyze molecular systems with state of the art 4D characterization techniques. Understanding and modulating complexity are underlying elements in a unique systems approach in chemical biology and (nano)materials research to advance the development of regenerative medicine and nanomedicine.
Prof. Jan van Hest has been appointed (50%) as the chair Bio-organic Chemistry (2016), and since 2018 as the scientific director of the ICMS. This cluster has furthermore been strengthened with the promotion of Patricia Dankers to the chair of Biomedical Materials (2018) and Ilja voets to the chair of Soft Matter (2018, 50%). Also in 2018, dr. Lorenzo Albertazzi joined the cluster as an associate professor, strengthening the cluster in the field of molecular biosensing. Very recently, prof Willem Mulder was appointed as chair Precision Medicine. Associate professor Tom de Greef was appointed on budget made available via the first *sectorplan*. The cluster has invested significantly in state of the art characterization methods to analyze the structure and dynamics of molecular assemblies. Research is aligned on a national level via the gravitation programs FMS and MDR.

Quality and Impact:
- Several ERC Grants, ERC PoF Grants, Veni/Vidi/Vici Grants, Top Grants a.o. 2 running ERC Advanced Grants (Meijer, van Hest)
- Gravitation programs Functional Molecular Systems and Materials Driven Regeneration
- Several collaborations in EU H2020 programs including as coordinator
- 640 publications, 10,295 citations, FWCI: 1.8, fraction top-10% journals: 0.7, international collaboration: 43% (2013->2018, SciVal)
- ~18 doctoral degrees per year
- Founding father in Chemelot InSciTe biomedical program
- Patents in the domain of tissue engineering, molecular diagnostics and nanomedicine, spin-offs and start-ups such as Suprapolix and Xeltis

Master tracks:
- Biomedical Engineering (CROHO 21PG-66226)
- Chemical Engineering (CROHO 21PG-60437)
- Specialization Molecular Systems and Materials Chemistry

Size and intended expansion of the permanent scientific staff (31-12-2018)
- Size staff: 15
- Requested expansion: 2

The total permanent staff of the cluster is 15 (in fte: 5.6 full-time professors, 3.8 associate professors, 0.8 assistant professors). The cluster employs 16 postdoctoral research fellows and 40 PhD students (2018 numbers). The request for expansion concerns 1 full time professor and 1 tenure-track position.

8 Requested positions

8.1 Sustainable Process Technology

The chemical process industry faces immense challenges related to pressing demands for feedstock diversification and reduction of energy consumption and CO2 emissions. Chemical reactors constitute the heart of basically all chemical processes and as such optimal design and operation of these units is of paramount importance for energy efficient conversion of feedstocks to desired products with minimal production of waste products. Key aspects include the development of novel catalytic reactors employing hierarchical multi-scale structuring, flexibility in operation (feedstock, scale), alternative modes of energy input (heat, microwaves, plasma, electricity). In addition there is a need to intensify processes by combining reaction and separation in an efficient manner to achieve strong synergistic effects. The transition to a circular economy in which valuable components need to be recovered from waste requires tailored separation at a molecular level. This challenge is at the heart of the discipline of chemical process intensification and requires proper attention to the underlying physical and chemical processes. Complementary to the existing expertise in membrane separation, there is a need for expertise in the design and development of novel solvents and sorbents which can be integrated in novel multiphase chemical reactors to significantly improve chemical conversion and selectivity.

8.2 Materials Chemistry & Functional Materials

Materials science is one of the key disciplines to provide answers to important societal challenges related to sustainability and environmental impact. In the next decades the transition from a fossil-based to a renewable energy economy requires the development of materials that can aid in efficient energy conversion and that are reusable, with limited environmental effects and burden on resources. TU/e is a traditional stronghold in organic and polymer science for materials development. In order to further strengthen its position as leading center of expertise, polymer science with a focus on recyclability will be developed for existing polymer materials and novel material concepts. This activity is highly complementary to activities in for example Wageningen and Groningen that are focused on biodegradable polymeric systems. One of the new lines of investigation with a typical Eindhoven trademark involves the exploration of supramolecular chemistry for self-healing, recyclable, but also adaptive materials. Third, the efforts on organic solar cells for which TU/e is renowned, will be strengthened with a new initiative on energy materials. The three requested positions enhance the sustainability activities in materials science at TU/e based on clearly recognized and identified strengths.

8.3 Complex Molecular Systems

Molecules attain their properties via interactions with each other, both for biological and synthetic systems. To come to a more profound understanding on molecular structure-property relationships, molecular interactions should be investigated with increasing levels of complexity in a controlled manner, to finally reach the level of an actual biological system. This systems approach will only be viable if theory, experiment and analysis go hand in hand. TU/e has embraced a systems approach to molecular assembly in the design of complex molecular systems at the interface with life science. Firmly based in two gravitation programs (FMS and MDR), and following an interdisciplinary approach this *focusgebied* has made much progress in recent years to push the limits of self-assembly, which is to be strengthened by increasing the interaction between theory and experiment. First, a computational modeling approach is needed to elucidate the rules that determine molecular self-assembly. Secondly, to translate the experimental expertise to biological applications, a position is requested to design and create immunomodulatory nanomaterials. The position computational modeling is complementary to other positions requested, such as the out-of-equilibrium theoretical position in Nijmegen, which aims at larger structures and is less molecule-based. The position of immunomodulatory materials follows a more nanomedicine approach compared to the activities within the gravitation program Institute for Chemical Immunology. As such, both positions are strongly embedded in the Eindhoven scientific tradition and are not duplicated by other initiatives.

TU/e: Chemistry: Requested Positions			
P	Individual positions and subsequent research themes	ZP	
1	*Sustainable Chemical Reactor Engineering*. The full professor position is at the heart of chemical engineering and covers the development of novel catalytic reactors employing hierarchical multi-scale structures, flexibility in operation in terms of feedstock and scale of operation, alternative modes of energy input including supply and/or removal of heat such as microwaves, plasma conversion and electrochemical conversion and photocatalysis. The position ensures continuity of the TU/e research and education in this important area of research.	I	

2	*Circular Polymer Materials*. A fundamental transition is required in the field of polymeric materials from synthesis out of fossil-based feedstock and one-time use, to continuous re-use of polymeric products. Besides reducing carbon footprint, this transition also poses highly challenging academic research questions related to energy-efficient polymerization and depolymerization processes. The focus will be on existing polymers, including smart new monomers that can switch between polymerized and depolymerized states. This new full professor position ensures that TU/e polymer research is brought to full strength in this strongly emerging research area, and is crucial to train our students in this discipline and provide society with engineers who can contribute to a circular economy.	II	
3	*Computational methods for Complex Molecular Systems*. This full professor theoretical position will develop multiscale molecular models, design in silico experiments and perform advanced simulation and analysis approaches to study complex molecular systems, particularly regarding dynamic bioinspired materials, self-assembling structures and stimuli-responsive autoregulated systems. Specific topics include the dynamics of one-dimensional molecular assemblies, smart supramolecular systems that respond to external changes and (bio)molecules that act as signaling platforms and are able to direct self- assembly via selective interactions.	III	
4	*Supramolecular Inorganic Materials*. Functional materials that convert solar energy into electricity and enable energy storage will completely reshape the global energy sector. The new full professor position is meant to develop a radical new approach by using inorganic self-assembly for the construction of hybrid materials that can be explored as functional devices. Together with a planned investment in energy materials research, this chair will safeguard the leading position in the field of energy devices by introducing inorganic motives in the current program around organic devices. This also strengthens the inorganic chemistry discipline, which is essential for educating modern materials scientists. The topic of supramolecular inorganic chemistry is complementary to the existing supramolecular organic chemistry strength.	II	
5	*Affinity Separations*. This new TTUD position reinforces the activities in the discipline of Separation Technology (currently only membrane separations). The new person will bring expertise in design and development of novel affinity solvents and sorbents for the selective recovery and recycling of valuable components to be integrated in chemical processes and multiphase chemical reactors to significantly improve chemical conversion, selectivity and recyclability.	I	
6	*Supramolecular Materials Chemistry*. This new TTUD position is required to ensure a smooth transition for the macro-organic chemistry group when Prof. Meijer plans to retire. This group will continue under the leadership of Dr. Palmans. The combination of organic and supramolecular chemistry in relationship to new materials is unique for TU/e: this position creates a unique opportunity to ensure that the core discipline Organic Chemistry remains a strong pillar in the future.	II	
7	*Self-assembled immunomodulatory materials*. The new TTUD will design and develop a platform of self-assembled immunomodulatory materials and will study the correlation between the underlying physical organic chemistry and resulting biological effects on the immune system. The knowledge gained from this activity will be translated into a molecular engineering approach to develop therapeutic modalities to correct sub-optimally functioning immune systems. The TTUD will strengthen the interface between chemistry, materials research, and cell biology and has a unique role in translating physicochemical properties of nanoparticles to biological responses.	III	

Table 3: Overzicht investeringsplannen per discipline. Abbreviations: I: Sustainable Process Technology, II: Materials Chemistry & Functional Materials, III: Complex Molecular Systems.

9 Smart Parameters: goals and monitoring

9.1 Ambitions in diversity and gender balance

The Chemistry discipline at TU/e employs currently 46.9 fte payroll staff members of whom 7.8 fte are female (17%). The involved departments make substantial efforts to improve the gender balance and foster diversity among their staff. The recruitment process has been severely strengthened recently. Scientific profiles of new faculty positions are broadly discussed in the departmental scientific committees, followed by the installment of a search committee consisting of staff members from different departmental disciplines, at least one outside member and at least one female member. Focus is on attracting talented, preferably mid-career researchers with a proven track record who are eager to contribute to the open and collaborative values of the departments. Extra attention is paid to the identification of potential female candidates. Identified (female) candidates are actively contacted and upon mutual interest invited for an informal interview with faculty staff members. Important criteria are drive and enthusiasm for science and education and an ambition to develop an independent scientific career. This approach has already been fruitful as evident from the hiring of 3 ambitious female researchers among the 4 latest hires. The implementation of the *sectorplans* will contribute to a further increase of the fraction of female staff well beyond 20% (25% in 2024) and to reach the target of 20% female full professors by 2020.

Table 4: Nulmeting en streefwaarden voor bemensing per discipline.

TU/e Chemistry	**Ambition**
Permanent scientific staff (FTE, dd 31-12-2018)	51
Tenure trackers (in FTE)	4
Postdocs (FTE)	80
Women in scientific staff (FTE)	12
Women in tenure track (FTE)	2
Women in postdoc position (FTE)	30
% Women in new sectorplan positions	≥35%

9.2 Talent development

With respect to talent development, the departments use transparent criteria for selection and decisions on promotions (tenure, associate and full professor). The different aspects of an academic career such as research, education, organization and valorization are evaluated on a frequent basis by a promotion committee in which also scientists from other disciplines participate. All young tenure-track staff members are enrolled in a mentoring program, geared towards their needs as identified directly after recruitment in a development plan which is continuously updated.

Table 5: Te monitoren indicatoren mbt quality and relevance, per discipline.

TU/e Chemistry		**Ambition**
Quality	Competitive grants	×
	Awards	
	Papers (FWCI; % in top 5% Journals)	
	Av. number of citations per paper	
	Other parameters	
Relevance	NWA grants in M€	
	Topsectoren grants in M€	1 M€/year
	Societal collaborations (narrative)	
	Number of patents	5/year
	Number of Start-ups / spin-offs	0/y resp. 1/y
	Industrial collaboration	8.5 M€/year
	Size 2nd and 3rd tier funding	2nd: 10 M€/y 3rd: 16 M€/y

Narrative for Table 5. Educating the next generation of chemical engineers, chemists and biomedical engineers is the primary goal of the Chemistry discipline at TU/e. Whilst the strong link between education and research permeates throughout its BSc and MSc programs, this is most evident in the MSc programs. The learning experience in this phase is enhanced by involvement in graduation projects that address societal challenges, often in cooperation with partners such as the chemical industry. The high level of 3rd tier funding and the presence of ca. 10 part-time professors coming from private partners such as the chemical industry and hospitals ensures that students have a strong interaction with future employers.

Student intake numbers have increased in recent years and include an increasing share of female students, international students (e.g., ~30% in the BSc Chemical Engineering and Chemistry) and polytechnical students. For polytechnical (HBO) students, a pre-master program of 30 ECTS is available. Arrangements with specific HBO institutes (e.g., Avans, Fontys and Zuyd Hogescholen), provide students access to this HBO-TOP program, allowing them to already complete this pre-master program in the HBO BSc program. The involved TU/e departments offer their students a large international network involving academia (e.g., >50 partner institutions in Europe) and many bilateral contacts with institutions outside Europe. The departments also host a large number of interns from HBO (ca. 20 per year) and Erasmus exchange students from academic partner institutes (ca. 25 per year).

The Chemistry discipline at TU/e has a strong interaction with secondary schools in the region and beyond. The outreach team targets secondary school students and teachers. Life-long learning activities for teachers aim for continuous professional development, examples being development of new exam programs in chemistry, workshops on specific topics and an annual 'Docentendag', exposing the participants to state of the art developments in the chemistry field. The current network involves 150 high schools, 500 teachers and 75 technical educational assistants. The activities for secondary school students also support the choice process, in part by acquainting interested students with the departmental research. As of September 2013, the department of Chemical Engineering and Chemistry offers scholarships to highly motivated first-year BSc students ('STimuleringsbeurzen'). This instrument is funded by the revenues coming from start-up companies within the department.

It is the strong belief of the Chemistry discipline at TU/e that innovations in chemistry will be pivotal to the development of a prosperous and sustainable future. The involved departments maintain a high sense of urgency to contribute to dramatic societal changes such as the energy transition, climate change and healthy ageing by laying the foundation for breakthroughs in chemical conversion processes, functional materials and regenerative medicine. The primary contribution of the research staff consists of the creation and dissemination of new knowledge, increasingly in collaboration with national and international educational institutes. The economic impact of the research proceeds through strong cooperation with private partners, involving large industries such as AkzoNobel, BASF, Douwe Egberts, Dow, DSM, FrieslandCampina, Janssen & Janssen, Philips, SABIC, Shell and Unilever, and increasingly also small- and medium high tech enterprises and start-ups/spin-offs, often originating from activities in local ecosystems such as Brainport and Chemelot InSciTe. Chemistry at TU/e sees many possibilities to broaden the scope of collaboration across the knowledge and innovation chain on societal topics as envisioned in the new NWA and KIC schemes. It subscribes especially to the mission-driven themes Energy and Health. The departments and their staff seek to increase impact through interactions with the general public. They are actively using social media to make the public aware of research outcomes, they speak to different audiences (TEDx talks, Universiteit van Nederland, Science Café's) and contribute to 'publieksdagen'.

The departments emphasize an open and collaborative atmosphere among their staff in which different forms of collaboration are fostered. Team science is established within the departments with the aim to open up multidisciplinary projects from which principal investigators, BSc and MSc students as well as PhD students and postdocs benefit. A strong integrative form of collaboration gives rise to cross-disciplinary research, for which the TU/e broad CRT's are ideal platforms. These aspects of collaboration are not only of growing importance in acquiring funding at the national and international level. The departments subscribe to the principles of open science. Currently, efforts are made to identify best practices of research data management in order to make available data for reuse as broad as possible.

Table 6: Education (including PhDs) per discipline

TU/e Chemistry	**Ambition**
1st year Bachelor	250
% Women in 1st year Bachelor	40%
1st year Master	150
% Women in 1st year Master	40%
% 1st year Bachelor students graduated within 4 years	75%
% 1st year Master students graduated within 3 years	90%
Nr of PhD theses	47
% of PhD theses from women	33%
Nr of PDEng theses	25
% of PDEng theses from women	50%

COMPUTER SCIENCE

6 TU/e: Computer Science: 'Facultaire zwaartepunten'

CS/e forms one department with Mathematics. The Department has centered its research on five themes, *Data Science, High-Tech Systems, Cybersecurity, Complex Networks*, and *Computational Science*, with CS/e contributing to the first four. These four themes are solidly founded in the Data Science Center Eindhoven (DSC/e), the High Tech Systems Center (HTSC), the Eindhoven Institute for the Protection of Systems and Information (EIPSI) and the gravitation program NETWORKS. CS/e is well known for its work on process and data mining, on algorithms, on visualization, on security and on software construction and correctness. The themes provide a research agenda that admits different groups to contribute and thus provide synergy; the themes have also clear links to the educational programs offered by the department, to the CRTs defined by the TU/e strategy 2030, and to national research programs.

Research in CS/e varies from curiosity-driven to applied, and there is an extensive and fruitful collaboration with industry. Personal excellence is demonstrated by 4 VI grants, 1 ERC grant, a PI in the gravitation project NETWORKS, and several TOP grants, all in the past few years. Significant funding comes from European sources, NWO TTW (STW, Perspectief) and direct funding through companies. In total roughly 50% of the CS/e budget comes from external sources. Recently, a start-up of the security group was sold for over 100ME. The Brainport Eindhoven region offers unique opportunities for collaborations and applying our research. Contacts with major industrial partners are formalized into so-called Flagships, in which our department collaborates with major players in a structured manner, in particular on High-Tech Systems and on Data Science.

CS/e will use the *sectorplan* funds to strengthen its position in four (out of seven) national *focusgebieden*: *Algorithmics (2 positions), Machine Learning (ML, 5 positions), Security and Privacy (S&P, 2 positions)*, and *Networked Computer and Embedded Systems (NCES, 2 positions)*. The selection of the topics come from new trends in data collection and analysis, from research questions in our industrial collaborations, and from the need to have high-quality curricula on these topics. This disciplinary strengthening will be embedded into the themes Data Science and High-Tech Systems, with some positions offering clear links with the themes Cybersecurity or Complex Networks. (The theme Computational Science will be expanded through *sectorplan* funding in Mathematics, and Complex Networks will be further supported in this way as well.) The thematic approach helps us to develop larger proposals and take leadership for the NWA (both Data Science and High-Tech Systems). Next we discuss the four CS/e research themes and their relation to the national *focusgebieden* in more detail.

6.1 Data Science

Focusgebieden: Machine Learning, Algorithmics, Security & Privacy
Disciplinary strengths: Algorithmics, Data Mining, Process Mining, Visualization, Privacy (and, in math: Statistics).
Data Science (DS) concerns all aspects of collecting, managing, and analyzing data in order to create value. Data may be structured or unstructured, static or dynamic, and data can be very heterogeneous. The extracted value can be in the form of predictions, automated decisions, models learned from data, or visualizations delivering insights into the data. The heart of data science lies within computer science and statistics, but it also poses important legal, ethical and other questions. The Department has recognized the importance and multi-disciplinary nature of data science at an early stage by founding JADS[6] and starting a full-fledged Data Science educational program, including an EIT (European) master program.

Data-science research within CS/e is focused on developing novel methods for analyzing large data sets, and on understanding the possibilities offered by these methods as well as their limitations. The research builds on our strengths in several areas within computer science, in particular algorithms, data and process mining, and visualization (as well as on expertise in statistics from Mathematics).

TU/e is one of the founders of the Responsible Data Science consortium, together with among others UvA, VU, RUL, RUN, TUD, and CWI. Responsible Data Science is addressed in the NWA-route VWData, where TU/e participates in the steering board. Collaborations with Wageningen University have started on data science in the agro-food sector, and there are strong collaborations with Utrecht University on Algorithmics, and with University of Twente and TU Delft on large scale software analysis from a data-science perspective.

[6] Jheronimus Academy of Data Science (JADS), a collaboration of TU/e, Tilburg University, the province of Noord-Brabant, and the city of 's-Hertogenbosch on Data Science.

6.2 High-Tech Systems

Focusgebieden: Networked Computer and Embedded Systems, Algorithmics, Security & Privacy *Disciplinary strengths*: Model Driven Engineering, System Architecture, Networks, Security
The Brainport Eindhoven region is the heart of the High-Tech systems industry in the Netherlands and it is known worldwide for its advanced machinery. These systems are increasingly networked, distributed and software-intensive, and are generally referred to as Cyber Physical Systems (CPS). CPS includes the Internet of Things (IoT), the deep penetration of the Internet into the physical world. Engineering these systems comes with challenges caused by increased complexity and stringent requirements. Model Driven Engineering is increasingly adopted, leading to models becoming first class citizens, retained throughout the life cycle. The concept of Digital Twinning is an extreme example of using accurate models for virtualization of entire products. Life-cycle management of subsystems and components becomes complex as systems are integrated according to systems-of-systems concepts. Dependability of CPS systems is of utmost importance. In practice it leans on two pillars: rigorous validation and verification during the design process and self-management during run-time.

CS/e is in a unique position to address these challenges with its expertise on systems architecture, formal systems analysis, model-driven software engineering, and security; with its extensive network of industrial contacts in the Brainport Eindhoven region; and with its collaboration with other departments in the TU/e High-Tech Systems Center and in various educational programs.

6.3 Cybersecurity

Focusgebieden: Security & Privacy, Networked Computer and Embedded Systems
Disciplinary strengths: Security, System Architecture and Networking (and, in math: Coding Theory and Cryptography)
Security has become a major concern when developing software systems. Moreover, the interconnectivity of systems and the massive amounts of data that are being collected, stored and shared raise serious privacy concerns. In particular the Internet of Things comes with a very complex threat model. Security research at CS/e aims at realizing a more secure and privacy-preserving digital infrastructure. To attain this goal the cybersecurity problem has to be investigated broadly, taking engineering, deployment, management, and maintenance perspectives of systems and ICT infrastructures into account. Our research reflects this, and ranges from security deployment and management, to physical security and attack engineering. Topics include network monitoring and software security, secure data management, Physical Unclonable Functions, and quantum cryptography.

Security and privacy are cross-cutting concerns that play an important role in data science as well as in high-tech systems and thus the Cybersecurity theme has overlap with these two themes.

6.4 Complex Networks

Focusgebieden: Algorithmics, (Data Modeling and Analysis)
Disciplinary strengths: Algorithmics (and, in Math: Stochastics, Combinatorial Optimization)
Technological advancements have led to the creation of vast network structures for transport of people, goods, information, energy, and social contacts. It is of crucial importance for society that these networks and the processes on them are well understood, controlled and optimized. Network traffic often varies and also other external factors that influence the performance of a network fluctuate in unpredictable ways. Moreover, in many cases the network itself evolves over time. Hence, stochastic models are needed to understand and predict the behavior of complex networks. On the other hand, algorithms are needed to control and optimize networks.

Research on networks within Mathematics and Computer Science at TU/e combines the department's excellence in stochastics, algorithms, and combinatorial optimization. Research in this theme is done in the context of the Gravitation project NETWORKS and it has close connections to the theme Data Science.

Educational Portfolio

CS/e has an extensive educational portfolio, including various BSc and MSc programs as well as unique PDEng programs. The table below gives an overview of our programs.

Table 6.1.1: Overview of education programs in Computer Science TU/e

Name	CROHO	themes	Comments
BSc programs			
Computer Science & Engineering (BTI)	56964	all	Regular CS Bachelor
Data Science (DS)	55018	Data Science	With TiU
MSc programs			
Computer Science and Engineering (CSE)	60438	all	Regular CS Master
Special tracks within CSE			
• Data Science in Engineering (DSiE)		Data Science	
• Information Security Technology (IST)		Cybersecurity	With RU
• EIT Data Science (EIT-DS)		Data Science	
• Erasmus Mundus program Big Data Management and Analytics		Data Science	With four Europ. univ.
Embedded Systems (ES)	60331	High-Tech Syst	With EE@TU/e and 4TU
Special track within ES			
• EIT Embedded Systems (EIT-ES)		High-Tech Syst	EIT Digital Master School
Data Science & Entrepreneurship	65018	Data Science	With JADS / Den Bosch
Automotive Technology (AT)	60428	High-Tech Syst	With EE, ME@TU/e
PDEng programs			
Software Technology (ST)	N/A	High-Tech Syst	Regular CS PDENG
Data Science (DS-PDeng)	N/A	Data Science	With JADS / Den Bosch
Automotive Systems Design (ASD)	N/A	High-Tech Syst	With EE, ME@TU/e

7 Characteristics of the 'zwaartepunten' for which funding is requested

TU Eindhoven, Computer Science

Data Science

Scientific content:
Algorithmics [*focusgebied*: *Algorithmics*]. Algorithms form the core of any system for data analysis. Because the amount of data is growing even more rapidly than the available computing power, algorithmic efficiency becomes increasingly important. CS/e has an excellent position on algorithms, with two strong research groups whose research spans two important (and related) areas within the broad field of algorithmics: *algorithms for spatial data* and *network algorithms*. Furthermore, the database group focuses on the processing of very large data sets in an efficient manner, and has a strong algorithmic flavor.

Data and process mining [*focusgebied*: *Machine Learning, (Data modeling & analysis)*]. CS/e has two strong research groups working at extracting patterns and insights from data, which are core to data science. One group focuses on data mining and technology, which entails predictive analytics, automation of machine learning and exceptional model mining. The group uses and develops techniques within machine learning. Another group focuses on process mining, a unique expertise which aims to uncover the underlying processes that generate a given stream of event data. This technology uncovers processes as they actually took place, admitting deep understanding, but also checking of compliance with the original specification.

Visualization [*focusgebieden*: *Machine Learning (human in the loop), Algorithmics*]. Data visualization exploits the unique capabilities of the human visual system to detect patterns and trends in imagery, allowing users to discover patterns and outliers in data that would be very difficult to find without the aid of the human mind. In CS/e, the Visualization group develops novel visualization methods and tools to enable the exploration of large data sets in an effective and insightful way. Algorithmic problems underlying visualization are studied in the Applied Geometric Algorithmics group.

Quality and Impact:
- Within the research groups mentioned above, there are two VICI laureates, one VIDI and three VENI laureates, one TOP grant, and one ERC Starting Grant. Moreover, one of the researchers in Algorithmics is PI in the Gravitation Grant NETWORKS. A PhD student from the Visualization group won the award for best PhD thesis on visualization, worldwide.
- The groups are also active in the COMMIT2DATA program of the top sectors, in the EU ECSEL program, and in H2020 industry programs.
- Within CS/e the open-source process mining platform PROM was developed, which contains more than 100 packages developed by researchers from all over the world.
- The department has structural collaborative programs (flagships) on data science, one with Philips and one with KPN, funding more than 10 PhD and postdoc positions in total.
- Big Data is one of the routes in the NWA, and it was one of the eight routes that was awarded a kickstarter grant (VWData, where TU/e participates in the Steering Board).
- The visualization group delivered three successful spin-off companies in the last 15 years.

Masters:
- Computer Science and Engineering (CROHO: 60438), with Special Track Data Science in Engineering, and European programs *EIT Digital Data Science* and Big Data Management and Analytics (Erasmus Mundus program)
- JADS-Data Science & Entrepreneurship (CROHO: 65018)

We also have a JADS BSc program (CROHO: 55018) and a PDEng program on Data Science.

Size and intended expansion of the permanent scientific staff: The current staff (including tenure trackers) in the research groups mentioned above entails 32 persons / 26.7 fte (Note that the theme is actually larger as also Mathematics is involved). We wish to expand this theme by another 7 fte through the *sectorplan* funds.(We include tenure track positions in the numbers reported for permanent staff.)

TU Eindhoven, Computer Science

High-Tech Systems

Scientific content: *Model-Driven Engineering* [*focusgebieden*: *Networked Computer- and Embedded Systems, (Software)*]. The software that controls high-tech machinery – or any modern software system, for that matter – typically consists of thousands of components that need to communicate and collaborate in order for the system to function correctly. Together these components easily contain millions of lines of code. To get a grip on such enormously complex systems, formal models that specify the desired behavior are a necessity. Research in the department focuses on the development and usage of such models in all stages of the software engineering process.

One line of research centers on the analysis of (concurrent) systems. How can we model these systems such that we can automatically verify their correctness or detect errors in the design of the software? This research combines techniques from process algebra, semantics, model checking, logic, and satisfiability solving. Another line of research concerns the automatic generation of software from models, for instance using so-called domain-specific languages, and the extraction of models from legacy software.

Networked Embedded Systems [*focusgebied* in Sectorbeeld: *Networked Computer- and Embedded Systems*]. Networking and distribution are at the heart of modern ICT systems and services. In fact, with the rise of the Internet of Things (IoT) networking and distribution are the heart of our modern society with its millions and millions interconnected devices, many of which are deeply embedded. This poses many challenges. For example, how can we build and manage applications composed from distributed services? Or, given that the individual devices in a distributed system often have limited resources, how can we distribute these resources effectively? Security of IoT systems is another major concern. Our research into these questions focuses on quality aspects, which include performance, predictability (time), dependability, programmability, and security. A dominant issue is the software architecture of resource-constrained embedded systems, since this is the major factor influencing the quality of the system. This is crucial in many applications including automotive systems and medical equipment.

Quality and Impact:
- Together with a group of EU partners, a new standard for IP-based building (lighting) control has been developed.
- The mCRL2 toolset for software verification has been incorporated as backend into the Verum toolsuite, which is the major toolset for formally verified code generation in use by all major industries in Brainport Eindhoven.
- The course Software Verification has been transformed into a MOOC with over 7,000 registered learners.
- An NWA proposal around IoT security has been developed and submitted.

Masters:
- Embedded Systems (CROHO: 60331)
- Computer Science and Engineering (CROHO: 60438)
- EIT Digital Embedded Systems (CROHO: 60331)
- Automotive Technology (CHROHO: 60428)

The research topics in this theme are also highly relevant for our PDEng programs on Software Technology and on Automotive Systems Design.

Size and intended expansion of the permanent scientific staff: The current staff in the research groups mentioned above entails 27 persons / 24.8 fte. (Note that the theme is actually larger as also Mathematics is involved). We wish to expand this theme by another 4 fte through the *sectorplan* funds.

8 Requested positions

Theme Data Science. Seven positions are requested, two of which are senior. We strengthen Data Science as a whole by expanding on existing strengths in Data Mining, Algorithmics, Machine Learning (including aspects of security and privacy), and Visualization with the aim to become a major center for research and education in data science within Europe. All positions will support our BSc and MSc programs in Data Science.

Theme High-Tech Systems. Four positions are requested, one of which is senior. We aim to strengthen High-Tech systems by expanding on existing strengths in Model Driven Engineering, System Architecture, Distributed real-time systems and Security. Besides strengthening our research, this also supports our education programs, which call for more expertise in this area, and our collaboration with industry in Brainport Eindhoven.

National alignment on specializations and directions
Computer Science Departments in the Dutch universities have aligned their proposals through the *Informatica Platform Nederland* (IPN). In a first round this was done by choosing the particular directions (i.e., focus areas) most naturally matching to each institute. Within the focus areas, there has been further alignment between the respective heads of computer-science departments in a separate session organized through IPN, and whenever deemed necessary through discussion in smaller groups. This led to complementary choices for specific research topics, thereby strengthening the collaboration between universities.

CS/e has made agreements with TU Delft and Utrecht University on the topic of Visual Analytics. Visual Analytics and visualization in general are important tools in the analysis of extremely large data sets. Delft studies high performance and interactive algorithms; Utrecht looks at the visualization of ma- chine learning while CS/e wants to employ machine learning for improving visualization in the health domain. Further alignment is reached on Responsible Machine Learning with Groningen, VU Amsterdam, and University of Amsterdam. CS/e will continue in the algorithmic direction, i.e., in incorporating the responsibility aspects into algorithmic problems. Positions in the area of cybersecurity have been coordinated with RU, TU/e, UT, UvA, and VU.

Table 3: Overzicht investeringsplannen per discipline. Overview of positions, with the corresponding Focus Area from the national Sectorbeeld (Alg=Algorithmics, ML=Machine Learning, S&P=Security & Privacy (S&P), NCES=Networked Computer and Embedded Systems) and the requested funding. We first list the positions in the Data Science theme, and next the positions in the High-Tech Systems theme, but the priority in the first column shows the overall priority.

TU/e: Computer Science: Requested Positions			
P	Individual positions and subsequent research themes	ZP	
Positions in Data Science			
1	**Responsible Machine Learning** This position strengthens our current research on Machine Learning in the Data Mining group. Together with the other positions, this position will establish a new group on machine learning. This position builds upon our work in Responsible Data Science. 'Responsible' refers to methods that support accountability, confidentiality, transparency and fairness in the analysis, and also to the ethical use of data.	ML	
2	**Visual Analytics** Visual analytics concerns the integration of methods from statistics and machine learning with interactive visualization, aiming to take advantage of the strengths of man and machine. This position will strengthen our position and increase collaborations, especially in healthcare: TU/e recently started the Eindhoven MedTech Innovation Center e/MTIC.	ML	
4	**Data Privacy and Security** Privacy is the control of data about one-self and the use of such data in an agreed context. The increasing availability of data and a lack of control represents a threat to privacy. Security techniques need to be adapted or developed for new challenges of highly distributed data gathering and beyond. Within the context of data science, the focus lies on the relation between information retrieval, privacy and data protection. This position adds to our current strength in monitoring, trust-based computing and policies.	S&P	
6	**Natural Language Processing** NLP is an expertise required in a broad range of applications and is increasingly important in our collaborations, and also in our teaching. Statistical methods and unsupervised deep learning techniques for language processing are the focus of this position. This is an important and highly active field that connects as an application area to our work on machine learning and mining.	ML	

8	**Distributed Data Analysis** Trends in distributed data collection call new techniques that allow an efficient global analysis to be performed in a distributed fashion; and also, new algorithmic methods are needed to analyze huge data sets in a rigorous manner, for instance using topological methods. We want to establish two positions in this area, one of which will be funded through *sectorplans* means. Both positions clearly fall into the Data Science theme, but are also related to the themes Networks and High-Tech Systems, especially in the context of the Internet of Things.	Alg	
9	**Causal discovery** Discovering causal relations is essential for all empirical sciences. Sound and scalable causal discovery from vast amounts of observational data of all kinds remains one of the key challenges in machine learning. This position will strengthen our position in explainable and interpretable machine learning and AI.	ML	
11	**Bayesian Machine Learning** Bayesian Machine Learning is one of the core foundations of AI. It is present in a wide variety of state-of-the art approaches and contributes to development of modern AI and ML techniques, notably, Deep Learning. This position will strengthen our position in AI, machine learning/deep learning and data mining. The position also connects to the Statistics group in Mathematics.	ML	
Positions in High-Tech Systems			
3	**Engineering of Software-Intensive Systems** Huge steps have been made in Model Driven Engineering enabling the engineering of evermore complex systems. MDE is also greatly affecting the workflow of system design and evolution, for example by the extreme virtualization known as 'digital twinning'. This position complements our current expertise in formal specification and validation, DSLs, and system architecture. The position will become responsible for teaching System Architecture and 'System thinking' to our master students and PDEng trainees.	NCES	
5	**Distributed Self-Managed Systems** Applications, systems and platforms have quality requirements, and sometimes these are critical (e.g., timeliness, or data flow). Performance requirements are understood for closed systems operating under known conditions. Open systems must deal with unpredictable conditions while still striving for utmost performance and handling data correctly. This position relates to our current expertise on Internet of Things and real-time systems. It is an important subject both for our MSc students and our PDEng trainees.	NCES	
7	**Security for the Internet of Things** The Internet of Things stands, in fact, for the Internet of tomorrow, where devices of all form factors, and deeply embedded into the physical world are connected by a shared protocol and naming scheme. IoT application are distributed as their platform is; data flowing through these systems crosses multiple domains. Protecting digital assets in this context is difficult due to a lack of management and a complex attack model that addresses devices, networks, services, applications and data. This position strengthens our current research in IoT and IoT security.	S&P	
10	**Algorithmic Aspects of Robotics and Manufacturing** Robotics and automation have revolutionized the manufacturing industry, increasing productivity by orders of magnitude at relatively low costs. The industry 4.0 trends poses challenges with respect to control and optimization of the overall process, many of which are of an algorithmic nature. This position complements our current expertise by focusing on more applied aspects. It also serves as a bridge between the themes High-Tech Systems and Data Science.	ALG	

9 Smart Parameters: goals and monitoring

9.1 Ambitions in research

Regarding our discipline of Computer Science, our ambition is simple: to achieve high scientific impact and to educate students to become highly qualified professionals. Impact requires focus, which we seek by bundling disciplinary strengths into themes. It is our goal to grow the two selected themes (Data Science and High-Tech Systems) further (in addition to the expansion through *sectorplan* funds) through extra means obtained by growing student numbers. We intend to live up to the ambitions stated in the founding of JADS and become the most important center for Data Science research and education in the Netherlands. We also want to establish laboratory support in both themes. For Data Science in particular the challenge is to provide full support to all parties to trustfully share their data.

9.2 Ambition in education and training of teachers

Training students is one of our most important tasks. We actively pursue cooperation in national and international programs (see the table in Section 6) to provide the most opportunities to our students, and to address the most needed specializations. We also collaborate with Fontys (HBO) in order to allow smooth transitions for students from TU/e to Fontys, and vice versa. In the future we want to strengthen these collaborations.

We already have a strong program on Data Science, with independent BSc and PDEng programs. With the proposed positions and together with Mathematics we will grow the current special track (within the CSE master) on Data Science into an independent master program with its own CROHO position.

The Department works with the Eindhoven School of Education (ESoE) on the education of new teachers and training of experienced teachers. Through ESoE we aim to take further leadership in this, in the form of the national Beta4all program and the Inf4all that is part of it.

9.3 Ambitions in diversity and gender balance

Complementing the TU/e policy as described in section 5, Computer Science will use the plans to increase diversity in a broad sense, including gender balance and nationality. The aim is that at least 50% of the new positions contribute to this diversity goal. To this end we advertise in a careful and neutral manner, we train our recruitment staff, we scout for candidates that can increase diversity, and we help them solve problems, like the '2-body problem' related to moving to Eindhoven. For positions and applications that improve the balance in diversity we will provide extra support, for example, in the form of additional research positions.

Table 4 below lists the current situation and our ambitions in terms of personnel. Tables 5 and 6 list basic parameters regarding quality and quantity of our research and education.

Table 4: Nulmeting en streefwaarden voor bemensing per discipline.

TU/e Computer Science	**Ambition**
Permanent scientific staff (FTE, dd 31-12-2018)	58
Tenure trackers (in FTE)	15
Postdocs (FTE)	20
Women in scientific staff (FTE)	11
Women in tenure track (FTE)	6
Women in postdoc position (FTE)	9
% Women in new sectorplan positions	≥35%

Table 5: Te monitoren indicatoren mbt quality and relevance, per discipline.

TU/e Computer Science		**Ambition**
Quality	Competitive grants	×
	Awards	
	Papers (FWCI; % in top 5% Journals)	
	Av. number of citations per paper	
	Other parameters	
Relevance	NWA grants in M€	
	Topsectoren grants in M€	0,1 M€/year
	Societal collaborations (narrative)	
	Number of patents	1/year
	Number of Start-ups / spin-offs	2/y resp. 1/y
	Industrial collaboration	8 M€/year
	Size 2nd and 3rd tier funding	2nd: 2,5 M€/y 3rd: 9 M€/y

9.4 Societal collaborations

It is our belief that a deeper understanding of the fundamentals of Computer Science makes a difference in solving societal problems. Computer Science has been at the heart of innovations that reshaped the world. CS/e has a tradition of making this connection through collaboration with industry, and in addressing societal concerns. Our PDEng programs are an important carrier of collaborations with industry.

The setup of our Data Science theme offers excellent opportunities to collaborate with companies, public institutions and government agencies. The recent Den Bosch location (JADS) targets entrepreneurial education and hosts start-ups; this is run together with Tilburg University. JADS is now fully operational, and in the coming years we plan to intensify our societal collaborations through JADS and through the Data Science Center Eindhoven (DSC/e). Our efforts in this direction will profit from collaborations with other departments within the TU/e, through the Cross Disciplinary Research Theme (CRT) on Data-Driven Intelligent Systems. At the national level we synchronize data-science efforts through DSPN.

The Brainport Eindhoven region is the heart of the High-Tech systems industry in the Netherlands and it is known world-wide for its advanced machinery, and of great importance to the Dutch Economy. We have an extensive network of industrial contacts in the Brainport region, as well as collaboration with other departments in the TU/e High-Tech Systems Center, which we keep on exploiting in the future. We take an active role in the NWA by leading a large initiative on Cyber Security.

In both Data Science and the High-Tech systems theme there are structural collaborations with major industrial parties like Philips, ASML, KPN and others, and we have links with CBS and with 'Rijkswaterstaat'. We want to expand these structural collaborations, whioch allow us to secure a steady stream of 3rd tier funding, but we also want to collaborate with and transfer knowledge to small and medium-size enterprises in Brainport Eindhoven.

Data Science and High-Tech Systems are both important for the health domain, which is a Strategic Area for TU/e. TU/e recently started the Eindhoven MedTech Innovation Center (e/MTIC) in which several hospitals, TU/e and Philips cooperate. Through e/MTIC, we wish to increase the impact of our research in the health domain.

Table 6: Education (including PhDs) per discipline

TU/e Computer Science	**Ambition**
1st year Bachelor	550
% Women in 1st year Bachelor	25%
1st year Master	250
% Women in 1st year Master	25%
% 1st year Bachelor students graduated within 4 years	70%
% 1st year Master students graduated within 3 years	80%
Nr of PhD theses	18
% of PhD theses from women	35%
Nr of PDEng theses	46
% of PDEng theses from women	30%