

4TU.Federation

Annual report 2021

April 2022

Table of Contents

Activities reports

Foreword	3
----------	---

Management

1	General Management Board & Executive Committee	4
2	Research Management Committee	6
3	Education Management Committee	9

Management

4	IMPACT	13
5	Applied Mathematics Institute	15
6	Built Environment	16
7	Design United	17
8	Energy	18
9	Ethics and Technology	19
10	High-Tech Materials	20
11	Humans & Technology	21
12	NIRICT	22
13	4TU.ResearchData	23
14	Centre for Engineering Education	24
15	Centre for Resilience Engineering	25
16	Stan Ackermans Institute	26

High Tech for a Sustainable Future

17	High Tech for a Sustainable Future	28
17.1	DeSIRE	28
17.2	Plantenna	30
17.3	Precision Medicine	31
17.4	Pride and Prejudice	32
17.5	Soft Robotics	33

External relationships

18	External relationships	34
19	Visibility	35

Foreword

The 4TU.Federation, the alliance between the four universities of technology in the Netherlands, is committed to strengthening and pooling technical knowledge. The universities of technology want to ensure that there are sufficient and well-trained engineers and technical designers and that leading international and socially relevant research takes place, and to promote collaboration between research institutions, businesses and public organisations.

2021 was for me the last full year as Chair of 4TU and that always leads to reflections on the more distant past. It seems like only yesterday that Wageningen University & Research joined the Federation of technical universities in 2016, thereby creating 4TU. In 2019 I succeeded Victor van der Chijs as Chair of 4TU. It has been a dynamic period in which a great deal has happened, in which new centres such as the 4TU Centre for Resilience Engineering were set up, partnerships created and ideas shared. Over the years the number of students has increased by well over 20% (from 53,062 in 2016 to 65,131 in 2021), as has the number of staff (from 14,358 in 2016 to 17,230 in 2021), albeit less rapidly.

Thanks to the Sector Plan for Science and Technology Education 4TU is involved in several projects which are intended to make technical degree programmes more attractive and further increase intake capacity. After all, there is still a huge need for good engineers. Research has also experienced growth. The 4TU research is concentrated in the centres, of which there are now 10, plus 5 thematic programmes in 'High Tech for a Sustainable Future'. Lastly the Techrede has also enabled us to put 4TU on the map politically.

All that positive energy and those worthwhile activities are the products of collaboration throughout the entire 4TU organisation. For that I would like to thank everyone most sincerely and in particular my colleagues on the 4TU board and the previous and current secretaries, IJsbrand Haagsma and Marjolein Dohmen-Janssen.

I am full of confidence as I pass the baton on to Vinod Subramaniam. I have always drawn a great deal of inspiration from the cooperation which 4TU generates and I wish you much of the same as you read this annual report and look to the future.

Louise O. Fresco
Chair of the 4TU.Federation (until March 2022)
President of the Executive Board of Wageningen University & Research

1 General Management Board & Executive Committee

General Management Board	Tim van der Hagen, Rob Mudde, Marien van der Meer (TU Delft) Robert-Jan Smits, Frank Baaijens, Nicole Ummelen (TU/e) Victor van der Chijs/Vinod Subramaniam, Tom Veldkamp, Mirjam Bult/Machteld Roos (UT) Louise Fresco (Chair), Arthur Mol, Rens Buchwaldt (WUR)
Executive Committee	Louise Fresco (Chair), Tim van der Hagen, Robert-Jan Smits, Victor van der Chijs/Vinod Subramaniam
Support	Pieter Munster and Eva Verschoor (WUR) Lotte Melenhorst (TU Delft), Renee Westenbrink (TU/e) Jasper van Alten en Lisette Woud (UT)
4TU	Marjolein Dohmen-Janssen, Linda Baljeu

The General Management Board (GMB) met twice (online) and the Executive Committee (EC) four times, including once in person. The Executive Committee also held an online meeting with a delegation from the employee participation body.

Personnel changes

In 2021 there were various changes in personnel within the EC and GMB of 4TU. Victor van der Chijs and Mirjam Bult left UT in April and August and were succeeded in September by Vinod Subramaniam and Machteld Roos respectively. The position of VPO in the EB of TU Delft has been filled by Marien van der Meer since 1 August. After the departure of secretary IJsbrand Haagsma (in November 2020) the new 4TU secretary, Marjolein Dohmen-Janssen, started work on 1 March 2021.

Political developments

The elections took place on 17 March 2021 and that eventually resulted in mid-December in a coalition agreement and a new government at the beginning of 2022. Although few political decisions were therefore taken in 2021, the EC and GMB regularly discussed the political situation and how they should prepare for new policy. Often the link was made with the Knowledge Coalition and/or the Universities of The Netherlands (UNL).

Activities plans 2022-2025

2021 was the last year of the current 4TU planning period. In preparation for the new period a short self-evaluation was distributed to the 4TU.Centres at the end of 2020 and at the beginning of 2021 they were asked to develop their plans for 2022-2025. After receiving advice from the research, education and valorisation management committees, the GMB approved the plans of the majority of centres in June. The Humans & Technology centre is going to be discontinued after 2021. Approval was given for the start of the new 4TU.Health centre as of January 2022. The proposal by 4TU.Research was also adopted to put out a call for a second round of the 4TU *capacity building programme* High Tech for a Sustainable Future.

Communication strategy

Since the beginning of 2020 4TU has paid extra attention to improving its internal and external visibility. The hired communication consultant has set up a number of important means of communication, including a newsletter and social media. In 2021 the EC decided to update the 4TU website and the work had more or less been completed at the end of 2021. A new communications strategy was also drawn up, whereby the EC chose to focus, in the external communication, on highlighting the successes of the four TUs (individually and jointly) and to communicate about the 4TU collaborations, particularly in the internal communication channels.

Drivers of Technology and Techrede

In 2021 the 'Drivers of Technology', in other words students committed to accelerating transitions, started to look for answers to questions from the first Techrede in 2020. They did so in the form of a Transition Tour in which they organised away days and hackatons with stakeholders from the industry, the government and politics. The answers and new questions which that generated were presented during the second Techrede on 16 September, which was the Thursday before budget day in the

Netherlands (Prinsjesdag). The Drivers provided regular updates to the EC who also provided them with valuable advice.

Key indicators

The number of assistant, associate and full professors (in FTEs) in the 2010-2020 period is shown in the tables below. The result of the structural focus on the recruitment of female research staff is clear.

Numbers of academic staff (assistant, associate, and full professors in FTEs), male and female, 2010-2020

MALE	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	20/19	20/10
TU Delft	751	754	734	726	731	735	744	757	775	787	832	+6%	+11%
TU/e	462	453	447	438	435	432	454	444	440	451	452	0%	-2%
University of Twente	486	467	452	434	421	417	418	423	435	460	498	+8%	+2%
Wageningen University	398	397	408	408	405	405	390	391	385	387	408	+5%	+3%
FEMALE	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	20/19	20/10
TU Delft	128	139	146	161	167	178	185	196	215	233	286	+23%	+123%
TU/e	62	65	58	73	81	98	108	114	120	132	165	+25%	+166%
University of Twente	117	121	118	117	114	115	119	127	145	151	175	+16%	+50%
Wageningen University	106	115	121	123	132	144	152	162	170	189	211	+12%	+99%
4TU % female	16%	18%	18%	19%	20%	21%	22%	23%	24%	25%	28%	+12%	+75%

Source: WOPI, reference date: 31 December

2 Research Management Committee

Management	Arthur Mol (WU, chair) Tim van der Hagen (TU Delft), Frank Baaijens (TU/e), Tom Veldkamp (UT)
Support	Pieter Munster (WU, secretary), Birgit van Driel (TU Delft), Rianne Pas (TU/e), Jasper van Alten (UT)
4TU	Marjolein Dohmen-Janssen, Linda Baljeu

In 2021, the Research Management Committee consisted of the research portfolio holders of the Executive Boards of the four universities of technology. 4TU.Research is responsible for the realisation and supervision of the collaboration and planning by the universities with regard to research.

Activities plan 2022-2025

During the reporting year, the committee considered the research component of the activities plan of the 4TU.Federation. The focus was on collaborating in socially relevant fields and on contributing to the visibility and impact of technology. Following an evaluation of the 4TU.Centres by the board, it was decided to finance nine centres: the continuation of eight existing centres, the termination of 4TU.Humans & Technology and the transformation of the activities of the steering committee *Health@4TU* into a centre named *4TU.Health*.

The activities and results of the *High Tech for a Sustainable Future* (HTSF) programme help raise the external profiles of the four universities of technology and promote intensive collaboration between and among disciplines, especially through the appointment of *tenure trackers*¹. In 2021 the Research Management Committee also decided to include a second round of this successful programme in the activities plan.

HTSF Call 2021

Following an initial request to consortia of the four TUs to submit an *Expression of Interest* for a new HTSF call 2021, three themes were adopted by the deans (or equivalent at WUR) on the basis of this input. This resulted in the definitive call to submit programme proposals in the field of: 'Materials and high-tech sensing technologies for the ageing built environment' (1), 'Low-cost sensing technologies for health' (2) and 'Sociotechnical approaches towards data-driven sustainable food systems' (3). In December, 4TU organised a well-attended online matchmaking event in order to bring together as many researchers as possible and thereby increase each proposal's chance of success. The call is closing in March 2022 and the expectation is that an announcement will be made in May regarding which proposals are to be approved.

HTSF Call 2017

In 2018 a total of €22 million was set aside for five themed programmes from the organisation's own resources within the framework of the first HTSF call: *DeSIRE*, *Plantenna*, *Precision Medicine*, *Pride & Prejudice* and *Soft Robotics*. An update for each programme is given in Chapter 17.

Health@4TU

For a number of years cooperation has been taking place within 4TU in the field of health and care, under the banner of Health@4TU. This has created a central point of contact at the universities of technology. The importance of technology for affordable and staffable care is highlighted by Health@4TU to the government, NWO, ZonMW and health funds. On basis of the plans and results the board has decided that the steering committee will become a centre as of 2022 and that the activities will be carried out in the future under the name of 4TU.Health.

¹ Talented young academics with the prospect of a permanent appointment

Key indicators

Number of 4TU doctorates, 2011-2021

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
4TU	917	973	1,064	1,145	1,130	1,182	1,063	1,161	1,230	1,083	1,200	+11%	+31%
TUD	319	303	353	371	357	395	359	368	400	374	432	+16%	+35%
TUE	199	245	218	243	234	224	212	264	290	244	268	+10%	+35%
UT	203	196	220	244	234	267	197	243	247	184	206	+12%	+1%
WU	196	229	273	287	305	296	295	286	293	281	294	+5%	+50%

Number of 4TU doctoral candidates present, 2011-2021

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
M													
TUD	1835	1854	1871	1881	1913	1959	1995	2021	1983	2038	2067	+4%	+21%
TUE	893	851	886	925	969	1028	1072	1070	1063	1105	1130	+6%	+33%
UT	839	831	784	784	783	756	751	699	648	798	843	+30%	-1%
WU	929	994	963	962	953	938	933	912	922	1026	1073	+16%	+18%
F													
TUD	681	713	730	744	739	751	771	795	828	890	936	+13%	+53%
TUE	312	308	324	355	398	415	462	494	509	541	557	+9%	+81%
UT	445	421	409	420	452	436	442	429	383	456	499	+30%	+21%
WU	872	965	992	941	943	929	938	955	1014	1170	1224	+21%	+56%
4TU	6,806	6,937	6,959	7,012	7,150	7,212	7,364	7,375	7,350	8,018	8,329	+13%	+30%

Source: WOPI (reference date: 31 December)

Prizes

The following prizes were awarded in the 2021 reporting year. The titles of the grants should not serve as a guide. For example, the Vici 2019 grant was awarded in April 2021, and is therefore included in this annual report.

Innovative Research Incentives Scheme	ERC
Veni 2021: awarded in December 2021	Starting: <i>not awarded in 2021 (01/2022)</i>
Vidi 2020: awarded in July 2021	Advanced 2020: awarded in April 2021
Vici 2020: awarded in April 2021	Consolidator: <i>not awarded in 2021 (05/2022)</i>

TU Delft	<p>Veni 2021 K. Bastiaans E. Greplova K. Kirchner K. Lahabi M. Russ C. Urzua Torres Y. Wang</p> <p>Vidi 2020 G. Giardina L. Marchal-Crespo</p> <p>Vici 2020 C. Joo</p>	<p>Starting 2021 <i>Awarding in 2022</i></p> <p>Advanced 2020 B. de Schutter P. van Mieghem</p> <p>Consolidator <i>Awarding in 2022</i></p>	Wageningen University	<p>Veni 2021 M. Diender J. van Hooff R. Huisman A. Kuhn B. van der Meer M. Zwetsloot</p> <p>Vidi 2020 I. Boas R. Staals N. Sutton</p> <p>Vici 2020 E. Frankema</p>	<p>Starting 2021 <i>Awarding in 2022</i></p> <p>Advanced 2020 -</p> <p>Consolidator 2020 <i>Awarding in 2022</i></p>
TU/e	<p>Veni 2021 P. Cosar</p> <p>Vidi 2020 A. Ravagnani</p> <p>Vici 2020 R. Duits J. van Leeuwen</p>	<p>Starting 2021 <i>Awarding in 2022</i></p> <p>Advanced 2020 K. Ito W. Mulder</p> <p>Consolidator 2020 <i>Awarding in 2022</i></p>	University of Twente	<p>Veni 2021 A. Betken H. Ruiz Euler</p> <p>Vidi 2020 B. Borsje N. Bosschaart C. Li</p> <p>Vici 2020 -</p>	<p>Starting 2021 <i>Awarding in 2022</i></p> <p>Advanced 2020 -</p> <p>Consolidator 2020 <i>Awarding in 2022</i></p>

Spinoza

In 2021 Professor Lieven Vandersypen (TU Delft/QuTech) received the Spinoza Prize which is the highest award in Dutch academia. This prize underlines the exceptional quality of Vandersypen's quantum research.

3 Education Management Committee

Management	Rob Mudde (TU Delft, chair), Frank Baaijens (TU/e), Tom Veldkamp (UT), Arthur Mol (WU)
Support	Hélène Bartelds (TU Delft, secretary), Lilian Halsema (TU/e), Lisette Woud (UT), Eva Verschoor (WU)
4TU	Marjolein Dohmen-Janssen, Linda Baljeu

In 2021, the Education Management Committee consisted of the education portfolio holders of the Executive Boards of the universities of technology. The committee is responsible for the details and monitoring of the working partnership between the universities in relation to teaching. This year dossiers of varying sizes were reviewed. A recurring topic for discussion was, for example, the TUs' struggle with high international intake and the limited opportunities for regulating it. The Stan Ackermans Institute provided updates on the PDEng and the eventually approved proposal for a name change to Engineering Doctorate (EngD). The 4TU.Centre for Engineering Education (CEE) was regularly in attendance to update the managers on current educational developments.

Education Activities Plan for 2022/2025.

In 2021, the board issued advice to the 4TU.General Management Board regarding the content of the 2022-2025 activities plan in the field of education. To that end the various bodies shared their long-term plans and budgets and these were discussed by the management committee. Financial contributions were again awarded to the CEE, Stan Ackermans Institute, NEMO Kennislink and a new 4TU platform for secondary school pupils.

Secondary education platform

Staff involved in linking secondary education with higher education put forward a proposal for an online 4TU platform for secondary education, with the aim being to prepare secondary school pupils more effectively for the transition to university. At the moment the linking programmes primarily operate at regional level in school networks and nationally via the secondary education-higher education networks. The 4TU platform represents the pooling of years of knowledge and experience in the field of cooperation in and with secondary education to send a single powerful signal to all teachers and pupils in the Netherlands. The board has allocated start-up financing to this initiative, with an option to extend.

Centre for Engineering Education

The four universities of technology are collaborating to improve engineering education through the Centre for Engineering Education (CEE). The centre collects and develops *evidence-based* knowledge and informs and advises the 4TU.Education board regularly on trends and innovations in education. CEE continuously monitors and analyses the effectiveness of innovations at the four institutions. The four TUs exchange expertise and experience, for example via the *CEE Innovation map*. At the end of 2021 this open database contained information about 274 innovation projects. The consequences of the pandemic on education are being monitored by various projects within the CEE and that is generating valuable insights. See also chapter 14, 4TU.CEE, for more information about this centre.

Sector Plan for Science and Technology Education

Following the recommendations of the Van Rijn Committee, the Ministry of Education, Culture and Science asked 4TU to draft a *Sector Plan for Science and Technology Education* in collaboration with the science faculties of the general universities, universities of applied sciences, student organisations and the business community. The plan involves the setting up of seven joint projects, the specific details of which were developed after the summer of 2020. The following is a summary of the progress per project. Updates on current progress can be found on the [4TU website](#).

Sector plan project 1b – Awareness

The aim of this project is to increase the teaching capacity of scientific and technical subjects (electrical engineering, mechanical engineering and computer science) by attracting (inter)national research talent via an *awareness* campaign. The project is to start with a feasibility study as the first

phase. On the basis of job market data and critical success factors this will enable an estimate to be made as to whether and how an awareness campaign can produce a satisfactory result.

Sector plan project 2b - Careers in, and the quality of, teaching

The focus of this project is on increasing opportunities for a teaching career in the context of university engineering/science education. The focus has been renewed and five specific work packages have been determined, namely the identification of types of teachers (1) and the range of professionalisation (2), the perception of quality indicators and criteria (3), the setting up and analysis of *Teacher Cultures Survey* at five fellow universities/science faculties in 2022 and 2024/2025 (4) and, finally, the definition of the project's final products and their communication (5).

Sector plan project 6a - National spread of teaching capacity

The aim is to work together to ensure a proper spread of the national teaching capacity and to make agreements about future capacity and the effective use of funding. Activities in 2021 were aimed at identifying the flows of students within the disciplines and at acquiring insight into the development of need on the job market. On request, NIDAP started quantitative job market research and published an interim report. Qualitative research is to follow in 2022. The project group also drew up a provisional list of courses of action in terms of regulating and adapting teaching capacity and then gathered relevant input from all the stakeholders involved.

Sector plan project 7b - Programme choice check

The aim of this project is for instruments to be jointly developed for the programme choice check [studiekeuzecheck] (SKC), (in the first instance) for electrical engineering, mechanical engineering and computer science, which can also be used for other programmes. The SKC has to reconfirm the programme choice or, in the event of an incorrect choice, help students find a more suitable programme. In 2021 the possibility was explored of a large-scale and broadly usable online tool. The corresponding budget turned out not to be achievable and eventually the decision was taken to refine the assignment.

Sector plan project 11 - Joint teaching materials

This part covers the encouragement and initiation of the joint development of teaching materials by science and technology course lecturers. Following an initial exploration and the creation of a project plan, it was decided to initiate qualitative research among teaching boards and boards of education. The interviews provided an insight into current initiatives, latent requirements, obstacles and desired support.

Sector plan project 13 - Develop LLO programmes

The aim is the joint coordination of supply and demand in terms of *Lifelong Development [Leven Lang Ontwikkelen]* (LLO) and the organisation of a (regional) approach to LLO. The team tried to link up with national initiatives and conducted exploratory discussions within the university and higher education communities and industry to continue building in 2022.

Sector plan project 14 - Promotion of electrical engineering

Awareness will be raised about electrical engineering and the possibilities that this broad programme offers within the entire chain of primary education, secondary education up to senior secondary vocational education, higher professional education and university education. The focus will be on new target groups, namely the people for whom electrical engineering is no automatic choice (girls, pupils with a migration background) and people who do not have any primary interest in electrical engineering, but are interested in the social areas of application. The project started with a gender scan of the university education programmes in electrical engineering in order to explore possible points for improvement. This generated interesting results and was followed by an adapted gender scan for higher professional education. A pilot is being developed with our partner, *Brainport*, with a focus on the appointment policy and retention of women and *internationals* in companies.

Key indicators

The significant increase in the number of students during the 2011-2021 period is illustrated in the following figures.

Number enrolled m/f, NL/international

4TU student population, 2010-2020, all students (primary enrolment as of 1 October)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
TUD	17,721	17,874	19,148	20,034	21,469	22,199	23,325	24,507	24,961	26,028	26,670	+2%	+50%
TUE	7,519	7,762	8,377	9,209	10,116	10,764	11,372	11,969	12,237	12,873	12,796	-1%	+70%
UT	9,398	9,314	9,315	9,263	9,082	9,396	9,921	10,665	11,404	12,219	12,609	+3%	+34%
WU	7,071	7,491	8,302	9,032	9,720	10,697	11,446	11,946	12,280	12,896	13,056	+1%	+85%
4TU	41,709	42,441	45,142	47,538	50,387	53,056	56,064	59,087	60,882	64,016	65,131	+2%	+56%
M	29,022	29,280	30,967	32,363	34,025	35,290	36,983	38,681	39,529	41,243	41,739	+1%	+44%
F	12,687	13,161	14,175	15,175	16,362	17,766	19,081	20,406	21,353	22,773	23,392	+3%	+84%

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
INT	6,461	6,839	7,246	7,688	8,726	9,895	10,905	12,209	13,154	14,191	15,742	+11%	+144%
NL	35,248	35,602	37,896	39,850	41,661	43,161	45,159	46,878	47,728	49,825	49,389	-1%	+40%

Intake BSc m/f, NL/international

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
TUD	2,790	2,756	3,057	3,125	3,274	3,353	3,641	4,094	3,783	3,943	3,859	-2%	+38%
TUE	1,591	1,729	1,967	2,144	2,276	2,396	2,616	2,338	2,296	2,535	2,258	-11%	+42%
UT	2,000	1,780	1,792	1,814	1,691	2,060	2,113	2,335	2,631	2,755	2,840	+3%	+42%
WU	1,102	1,181	1,457	1,484	1,521	1,655	1,713	1,711	1,620	1,734	1,544	-11%	+40%
4TU	7,483	7,446	8,273	8,567	8,762	9,459	10,083	10,478	10,330	10,967	10,501	-4%	+40%
M	5,116	5,092	5,657	5,793	5,956	6,149	6,725	6,869	6,664	7,056	6,884	-2%	+35%
F	2,367	2,354	2,616	2,774	2,806	3,310	3,358	3,609	3,666	3,911	3,617	-8%	+53%

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
INT	844	725	741	768	805	1,158	1,307	1,875	2,070	2,269	2,843	+25%	+237%
NL	6,639	6,721	7,532	7,799	7,957	8,301	8,776	8,603	8,260	8,698	7,658	-12%	+15%

Source: 1CHO

Key indicators

The following tables show that the number of Master's students at the four universities of technology has more than doubled over the past ten years. The number of Bachelor's degrees among international students rose again in 2021, while that of the Dutch students declined.

Intake + throughput MSc m/f, NL/international

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	21/20	21/11
TUD	1,240	2,089	2,327	2,519	2,207	2,882	3,393	3,500	3,459	4,107	4,162	+1%	+236%
	621	717	887	976	655	1,117	1,180	1,264	1,373	1,633	1,599	-2%	+157%
	567	847	688	667	471	1,072	1,122	1,117	1,195	1,284	1,308	+2%	+131%
	992	1,325	1,310	1,300	1,228	1,676	1,750	1,765	2,035	2,053	2,128	+4%	+115%
4TU	3,420	4,978	5,212	5,462	4,561	6,747	7,445	7,622	8,062	9,077	9,197	+1%	+169%
	2,098	3,170	3,243	3,516	2,893	4,131	4,577	4,666	4,858	5,558	5,591	+1%	+166%
	1,322	1,808	1,969	1,946	1,668	2,616	2,868	2,956	3,204	3,519	3,606	+2%	+173%
INT	1,711	1,858	1,867	2,219	2,773	2,889	3,117	3,114	3,098	2,918	3,554	+22%	+108%
	1,709	3,120	3,345	3,243	1,788	3,858	4,328	4,532	4,964	6,159	5,643	-8%	+230%

Number of BSc and MSc degrees m/f, NL/international

4TU BSc degree certificates, 2010-2020

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	20/19	20/10
4TU	4,338	5,542	4,875	4,955	5,565	5,175	5,617	5,962	6,440	6,685	7,288	+9%	+68%
	2,996	3,863	3,166	3,205	3,651	3,284	3,608	3,854	4,011	4,244	4,562	+7%	+52%
	1,342	1,679	1,709	1,750	1,914	1,891	2,009	2,108	2,429	2,441	2,726	+12%	+103%
INT	312	335	399	480	483	541	470	450	649	723	956	+32%	+206%
	4,026	5,207	4,476	4,475	5,082	4,634	5,147	5,512	5,791	5,962	6,332	+6%	+57%

4TU MSc degree certificates, 2010-2020 (including Master's degrees)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	20/19	20/10
4TU	5,054	5,892	5,556	5,987	6,416	6,960	7,540	8,045	8,448	8,434	9,733	+15%	+93%
	3,373	3,805	3,643	3,845	4,080	4,366	4,701	4,846	5,195	5,156	5,913	+15%	+75%
	1,681	2,087	1,913	2,142	2,336	2,594	2,839	3,199	3,253	3,278	3,820	+17%	+127%
INT	1,398	1,649	1,674	1,845	1,967	2,164	2,643	2,926	3,058	2,986	3,180	+6%	+127%
	3,656	4,243	3,882	4,142	4,449	4,796	4,897	5,119	5,390	5,448	6,553	+20%	+79%

Source: ICHO

4 IMPACT

Director	Paul Althuis (TU Delft)
Programme manager	Roelyn van der Hoek (UT)
Management team	Paul Althuis (TU Delft), Jeroen van Woerden (TU/e) Jaap Beernink (UT), Sebastiaan Berendse (WU)

The joint valorisation efforts of 4TU are based within the 4TU.IMPACT centre. It reports to the Valorisation Management Committee, consisting of the Valorisation portfolio holders of the four universities of technology. In 2020, these were Robert-Jan Smits (TU/e, chair), Tim van der Hagen (TU Delft), Victor van der Chijs (UT) and Rens Buchwaldt (WU). 2021 was the last year of the 4TU.IMPACT plan 2018-2021. A new activities plan was approved for 2022-2025. A few highlights from 2021 are described below.

Techrede speech

4TU.Impact guided the six Drivers of Technology with their activities for a follow-up of the Techrede. The result was presented at the Innovation Expo on 8 April 2021. During the Transition Tour the students held talks with various stakeholders. Numerous initiatives were presented during the 2021 edition of the Techrede and these reflected the desire of students to accelerate social transitions in consultation with politicians and industry. These ranged from the 'Preven-tientje' and the 'Melktap', to the Hydrogen Board.

Thematic Technology Transfer programmes

Impact promoted the *XPrize Carbon Removal Student Team* competition, for which three 4TU teams were formed, in cooperation with 4TU.Energy and the two Circular Technology Thematic Technology Transfer programmes (TTT). The quality of the contribution was so high that an internal 4TU competition was set up. The three teams are going to continue developing their concepts and assessing whether an application for a TTT voucher is one of the options.

In addition to the two TTT programmes in the field of *Smart Systems* and circular technology, which are going well and in relation to which several spin-offs have received a voucher, an application for a third programme in the field of medical technology has been approved.

Impact Challenge

The third edition of the 4TU Impact Challenge took place in 2021. The final was in Helsinki and this was followed by participation in Slush 2021 – The World's Leading Startup Event. Together with a few existing start-ups by the four TUs and Netherlands Enterprise Agency (RVO) a boot camp was first organised during which all participants were prepared and trained in how to ensure that their participation in Slush would generate the greatest impact. The cooperation with both the RVO and the Dutch embassy was a success and is going to be repeated next year.

The stories behind the spin-offs of the four TUs and TNO can be read and listened to in the Spin-off of the Spin-off series and a series of podcasts - which were a collaboration between 4TU and *Innovation Origins*. These demonstrate that a spin-off can have significant added value for researchers, precisely in the field of that research.

Techbuddys

A new initiative was started in March, namely Techbuddys. A number of team managers from student teams at the four TUs were linked to MPs so that they could be easily updated on technology developments.

KTO

4TU.Impact has committed itself to structural government funding of valorisation in the form of the basic infrastructure of the Knowledge Transfer Offices (KTOs) and early phase financing. As a consequence, Sebastiaan Berendse is now coordinating the Universities of The Netherlands (UNL) working group on early phase financing and Roelyn van der Hoek sits on the working group for the 'KTO The Netherlands' plan. The latter was launched prior to the Ministry of Economic Affairs and Climate Policy budget debate in the Dutch House of Representatives. During the debate MPs Pim van

Strien (VVD), Gijs van Dijk (PvdA), Tom van der Lee (GL) and Chris Stoffer (CU) submitted a motion in which the government was urged to carry out an assessment in the short term of the effort required to realise the ambitions of KTO The Netherlands, which also means looking at the broader aspects of valorisation, such as field labs and SME collaboration vouchers.

Commercial activity

This annual report covers business activity, which is an indicator of valorisation. Business activity is measured in terms of the number of spin-offs and start-ups. The international definitions of these terms, which are also used by the Universities of The Netherlands (UNL), have been adopted for the purpose of this report.

	Spin-offs	Start-ups
TU Delft	3	0
TU/e	6	15
University of Twente	5	29
Wageningen University	1	0

5 Applied Mathematics Institute

Scientific director	Johann Hurink (University of Twente)
Coordinator	Laurie Baggen (TU/e)
Management team	Kees Vuik (TU Delft), Luc Florack (TU/e) Richard Boucherie (UT), Peter van Heijster (WUR)
Board	Joost Kok (dean, UT), Johan Lukkien (dean, TU/e) Lucas van Vliet (dean, TU Delft), Peter van Heijster (WUR)

The overall aim of the 4TU Applied Mathematics Institute (4TU.AMI) is to encourage collaboration between mathematics groups and researchers at the four universities of technology, and thereby jointly promote the role of mathematics in fields of application.

Coordinator Laurie Baggen has accepted a new task within the TU/e and someone else is going to take over her role.

Strategic Research Initiatives

In order to be able to act in a more effective and targeted way 4TU.AMI will, in the future, use some of its resources for Strategic Research Initiatives (SRIs) which can be initiated by members of the four mathematics departments. These SRIs have a specific objective (for example jointly drafting a larger research proposal or starting up a new research field) and a limited term (2-3 years) and are supported by researchers from at least two of the TUs. An initial SRI about dynamic ecological systems is to start at the beginning of 2022.

Math4NL

In addition to the cooperation within the four TUs, AMI and the Dutch Platform for Mathematics [Platform Wiskundig Nederland] (PWN) have jointly started an initiative to strengthen the long-term cooperation between mathematics researchers and Dutch society. With this in mind a centre called Math4NL is to be set up with the aim being to simplify collaboration between mathematicians in the Netherlands and the business community. The aim of Math4NL is to set up the first projects and partnerships with industrial or social organisations in 2022.

New members of staff

In 2021 direct contact between the mathematics departments at the four TUs suffered due to the ongoing pandemic. The pressure of work in terms of primary tasks was substantial and, as a result, there was little energy left to invest in broader collaborations. Above all this means that the many new young members of staff (recruited in the last 2 years) are now facing a considerable challenge. As a consequence, AMI will spend a great deal of time on reinforcing the contacts within and between the TUs. In the summer of 2022, an event is to be organised at which the mathematics community within the four TUs can meet in person once again and will give new employees a platform to introduce themselves and make new contacts.

A communications officer was recruited in 2021 to continue expanding and strengthening the network function of 4TU.AMI. In addition to encouraging internal interaction between the four TUs, there will also be a focus on adding to the contacts with Germany within the framework of European cooperation. In doing so, specific attention will be paid to the 'Mathekalender', which is a German initiative aimed at secondary school pupils.

6 Built Environment

Scientific director	Maarten Hornikx (TU/e)
Coordinator	Maaïke Riemersma (TU/e)
Management team	Frank van der Hoeven (TU Delft), Erik Schlangen (TU Delft) André Dorée (UT), Sanda Lenzholzer (WUR)

In 2021 the activities of 4TU.Built Environment (4TU.BE) were focused on the Building and Technology Innovation Centre (BTIC), the representation in the Social and Economic Council of the Netherlands (SER), the setting up of theme-based teams and broader collaborative activities.

BTIC

4TU.BE plays an active role in the BTIC, in which Institutes of Higher Education and TNO, industry/Research for the Built Environment (OTB) sector and ministries are represented. In 2021 a proposal was submitted to the National Growth Fund, which is entitled 'Future-Proof Living Environment: Transition to Emissions-Free, Circular and Climate-Proof Buildings and Infrastructure [Toekomstbestendige Leefomgeving: Transitie naar Emissievrije, Circulaire en Klimaatbestendige Gebouwen en Infrastructuur]' which was accepted in February 2022. In 2022 the BTIC intends to be a Top Consortium for Knowledge and Innovation (TKI) within the Energy Top Sector.

The beating heart of the BTIC is the management team, whose members come from TNO, the building federations and 4TU.BE. Henk Visscher (TUD) represented 4TU.BE in the BTIC in 2021. As from 2022, Maaïke Riemersma and Anita Baas will succeed him with more capacity and support from the deans of the four TUs. 4TU.BE is also represented in the BTIC working group (Max Hendriks) and the BTIC Council (Theo Salet) and coordinates the delegation from its faculties in the BTIC Knowledge and Innovation Programmes. Cooperation with institutes of higher education takes place in the *Built Environment Lectors' Consultation Group [Lectorenoverleg Gebouwde Omgeving]* and BTIC.

SER Labour Market and Education core team

André Dorée (UT) represents 4TU.BE in the SER Labour Market and Education core team. Linking with the chain on innovation themes in the built environment is as important as it ever was. The pursued link between programme, practice and research has been followed up in the Growth Fund proposal through the creation of the *quadruple helix ecosystem*: Innovation, research, education and practice in various regional contexts is leading to innovations in the sector which are intended to address social challenges and increase earning power.

Theme-based teams

The centre's long-term plan 2022-2025 was approved in 2021, thereby enabling both the transition to a network organisation and the approach for achieving a long-term vision on social themes by 4TU teams to take shape. A start was made with the communication plan, the website and the first theme-based team on Digitisation. This is to be followed by teams on the themes of Circularity & Sustainability, Energy Transition, Infrastructure & Mobility and Area Development & Climate Adaptation.

In 2021 a great deal of work was done on drafting a 4TU.BE communication plan and on updating the website. This is to be continued in 2022 in order to support the network function, the theme-based teams and the cooperation within BTIC. Research and education will become more visible to the stakeholders and attempts will be made to cooperate with relevant 4TU centres.

The centre is committed to strengthening the cooperation with public and private organisations in the OTB sector and other stakeholders, for example through PDEng positions, cooperation in *Living Labs* and Innovation ecosystems.

Sector plan

4TU.BE has 30 tenure track positions in the Civil Engineering sector plan. The focus is on connecting researchers in order to improve innovation strength. Cooperation took place on the Sector Overview for Design Engineering Sciences that was presented to the Ministry of Education, Culture and Science (OC&W).

Scientific director	Berry Eggen (TU/e)
Scientific co-directors	Daan van Eijk (TU Delft), Mascha van der Voort/Daniël Saakes (UT), Dieuwertje de Wagenaar (WUR)
Management team	Ena Voûte (TU Delft), Lin-Lin Chen (TU/e), Mascha van der Voort (UT), Karin Schroen (WUR)

4TU.Design United (4TU.DU) contributes to the specialisation of design professionals by developing new knowledge and increasing access to existing knowledge. This improves the innovation strength of the industry, promotes economic growth and contributes to solving problems of society. 4TU.DU forms a community for Dutch research in design and it targets both designers and researchers, as well as relevant organisations.

The activities of the research centre have the following objectives: 'to connect, to communicate, to coordinate and to create'. 4TU.DU enhances its strength through its role in national discussions as a platform/point of entry for design research, in order to put design as a discipline on the map, and by helping set the agenda in the *Creative Industry top sector*.

Strategic contributions

In 2021 4TU.DU researchers actively contributed towards the development of visions and strategies for the Dutch creative sector. They did so via CLICKNL (the top consortium for knowledge and innovation of the Creative Industry top sector), but also by making a start, with the help of deans, on creating a sector overview of the Design Engineering sector. The sector overview served as a basis for the sector plan which was drafted in 2021 and which is to be presented in 2022.

DRIVE in hybrid form

CLICKNL and DU jointly organised the annual *Design Research and Innovation Festival* (DRIVE) during the Dutch Design Week in Eindhoven, this time in a hybrid form. Members of the public and the speakers came together live and online in inspiring sessions and workshops which revolved around five social themes: Mobility, Circular & Biobased Building, Health, Safety and Food & Water.

Up Close & Personal, online talk show and STRP-S physical exhibition

In 2021 the annual 4TU.DU exhibition during the *Dutch Design Week* (DDW) consisted of a new online edition of 'Up Close & Personal', although this time it was accompanied by a physical exhibition in the Klokgebouw at Strijp-S. Every day there was a live-stream talk show which focused on a different current design research theme each time. The talk shows were broadcast via social media and the 4TU.DU website and were backed up by an e-Magazine. The five themes, namely *Entangled Ecologies*, *Connected Interactions*, *Changing Things*, *Embedded Designers* and *Evolving Methodologies* shone the spotlight on 36 of the most provoking and yet accessible research products of the four TUs. The columns by 4TU experts and the critical perspectives of the external guests also prompted much reflection and in-depth analysis. The event not only reached a wide design audience, but once again made clear that the contributions by the 4TU design researchers extend beyond the boundaries of the faculties and that it is in fact their teamwork and complementarity that demonstrate the unique impact of the design sciences on the challenges facing society.

Design perspectives

Due to COVID-19 restrictions the new 'Design Perspectives' event which was planned in 2021 was postponed until 2022. The dates for the first two events have now been set in April and June 2022. They will bring different disciplines, researchers, students, and professionals together in theme-based meetings to find the best ways of generating impact through 4TU research into solutions to complex societal challenges. The meetings will provide input for the 4TU.Design United activities in the *Dutch Design Week* (DDW). The purpose, for 4TU.DU, is to help create a future-oriented sector perspective for the design engineering sciences and to focus on strengthening the discipline in 4TU and in the Netherlands. Plenty of discipline is needed to be able to create a robust link with the other 4TU disciplines and to show what the integrating role of the design engineering discipline can mean for 4TU and how it can be realised in concrete joint research projects.

8 Energy

Scientific director	David Smeulders (TU/e)
Management team	Gerrit Brem (UT), Harry Bitter (WU), Kornelis Blok (TU Delft)

The importance, distinctiveness and added value of 4TU.Energy lies in the reinforcement of the internal coherence between the four technical universities. The centre wants to link together young researchers from the four TUs and interest students and doctoral candidates in energy-related issues and specific research. In this way relationships can be established which would otherwise not come into being, or would be more difficult to create, for example in the form of staff exchanges, specific workshops and courses. This is essential for the training of the people required for the energy transition and for the development of the necessary scientific knowledge and new technologies which will enable the required steps to be taken in the coming decades in order to achieve a sustainable energy system.

Responsible Sustainability Challenge

The 4TU.Responsible Sustainability Challenge is currently under development. This challenge is an initiative by the 4TU.High-Tech Materials, 4TU.Energy and 4TU.Ethics & Technology centres and is being developed by tenure trackers. The course is going to start in September 2022. It concerns a 15 ECTS multidisciplinary project for 4TU Honours students (or students with a similar track). Students will be working in groups of 5 to 8 on a subject related to technological developments for social sustainability issues. The aim of the project is to develop sustainable technologies with a multidisciplinary group, whereby the technical solutions have to fit within a circular economy (e.g. a scarcity of materials), with assessment taking place against an ethical framework (e.g. a fair energy transition). The subjects are related to the EU package entitled 'Fit for 55'.

Carbon Removal Challenge

In 2021 4TU.Impact and 4TU.Energy jointly invited students to participate in a competition within the framework of the X-prize GigaTon Scale Carbon Removal, which was set up by Elon Musk. This 4TU Student Challenge started in May 2021 with a call to students to put forward ideas to remove CO₂ from the atmosphere and the oceans and then find a long-term storage solution for it. Enthusiastic teams of students from the four universities presented their solutions in October 2021. The prize was won by Team CryoCOP whose participants were students from all four technical universities. All the entries were also submitted for the main Elon Musk prize.

Videos

4TU.Energy also helps to highlight academic work on the topic of the energy transition in society. That is why the centre is creating short and accessible videos which demonstrate the joint contribution of the universities of technology to the energy transition in a clear and instructive way. They can also be used to highlight particular degree programmes and infrastructure. 'Towards a digital twin of our powergrid' and 'Wind energy challenges' are now available online, 'Biomass' has been completed and 'Heat' is being prepared.

Cooperation between 4TU.Centres

In the time ahead, 4TU.Energy is going to continue building on the cooperation with other centres. Within the framework of the Strategic Research Initiative Energy it is going to brainstorm with 4TU.AMI and a 'Joint Workshop' is to be set up with 4TU.Ethics & Technology and 4TU.High-Tech Materials.

9 Ethics and Technology

Scientific director	Anthonie Meijers (TU/e)
Managing director	Tijn Borghuis (TU/e)
Assistant director	Karen Buchanan (TU/e)
Management Team	Philip Brey (UT), Patrick Smith/Julia Hermann (UT), Vincent Müller (TU/e) Sabine Roeser (TUD), Filippo Santoni de Sio/Udo Pesch (TU Delft) Marcel Verweij (WUR), Zoë Robaey/Vincent Blok (WUR)

The national and international innovation agendas assign high priority to the development and application of methods and strategies for ethical and socially responsible technical innovations. The 4TU.Centre for Ethics and Technology (4TU.Ethics) is studying the ethical aspects of the development, use and regulation of technology. At the end of 2021, the 4TU.Ethics community had a total of 14 professors, 29 senior researchers, 20 post-docs and junior researchers, 64 doctoral candidates, and 83 affiliated members. The total number of members grew this year by 14.

Doctoral candidates and education

The 'Ethics of Socially Disruptive Technologies' (ESDiT) gravitation programme led to a substantial intake of new researchers and doctoral candidates into the 4TU.Ethics Graduate Course programme in 2021.

The 'well-being programme' for 4TU.Ethics doctoral candidates is continuing to take shape in collaboration with the centre's PhD Council. In addition to online linking activities, two new elements were developed to assist with career advice after graduate school. One is the option of a 6 week internship and the other is the setting up of an alumni network.

The Working Group on COVID-19 Crisis (WGCV-19) of 4TU.Ethics and the *Delft Design for Values Institute* are focusing on the ethical challenges presented by the pandemic. In 2020 the insights gathered from this research were shared with the general public, for example in a series of podcasts and with the academic world in a special issue of the *Ethics and Information Technology* journal. Additional publications and a PhD course are being prepared.

During the 'Ethics Education for Engineers' project (2019-2021, project manager Lavinia Marin, TU Delft) case-based exercises for teaching ethics to engineering students from the 4TU.Ethics community were collected, edited, combined and published as an open educational resource via the Ethics page on the [SURF edusources platform](#). Teaching materials on philosophy and the ethics of technology have been developed for secondary schools, in the context of the new 'online literacy' element of the curriculum.

Conference on Ethics and Technology

On 14 and 15 October 2021 well over 100 researchers met during the bi-annual Conference on Ethics and Technology. The conference, which was entitled 'It's Alive', was dedicated to ethical issues relating to the way in which humanity is able to manipulate living systems and nature and how technologies are changing people and nature. The conference combined a physical meeting in Wageningen with online sessionsⁱ. The keynote speakers were Bernice Bovenkerk (WUR), Alberto Giubilini (Oxford) and Nicole Vincent (University of Technology Sydney).

Funding

In 2021 4TU.Ethics members acquired funding for 17 new projects amounting to just under 2 million euros.

Transfer to WUR

As from 2022, 4TU.Ethics is to be coordinated via Wageningen: Marcel Verweij (scientific director), Vincent Blok (graduate programme director), Jochem Zwier and Mariska Bosschaert. They will place the focus on setting up and implementing the strategy for the period between 2022 and 2025.

10 High-Tech Materials

Scientific director	Jilt Sietsma
Coordinator	Reina Boerrigter
Management team	Bernard Dam (TU Delft), Rint Sijbesma, Marc Geers (TU/e) Remko Akkerman, Gertjan Koster (UT), Karin Schroën, Joris Sprakel (WU)

The primary objective of the 4TU.High-Tech Materials centre (4TU.HTM) is to stimulate and take a fresh approach to outstanding materials science research at the four universities of technology through collaboration and new initiatives relating to both research and teaching. The researchers involved represent many aspects of materials science, ranging from fundamental to applied research and from nanotechnology to constructions. Since 2015 4TU.HTM has been able to bring together materials science research in the Netherlands in this way. The priorities for the years 2019-2021 are teaching, the materials science infrastructure and the relationship with industry, e.g. via a strategic partnership with the Materials Innovation Institute (M2i).

Cooperation between researchers

By funding joint materials science activities 4TU.HTM is encouraging the cooperation between materials science researchers involved. The collaborative projects approved by 4TU.HTM in 2020 which could not be carried out due to coronavirus measures were followed up in 2021. In addition to the *proof-of-concept* experiments (Sissi de Beer, NWO/TTW Perspective Programme), this concerned a joint research proposal by TU Delft and WUR into smart materials and coatings and a research project into mechanical metamaterials, which was a joint project by TU Delft and TU/e in cooperation with a design studio. The latter resulted in October 2021 in the 'Adaptable Auxetics' exhibition during the Dutch Design Week in Eindhoven. This project included an assessment of how the TU/e's software model, which generates complex digital 2D structures, can be used to develop new physical 3D structures. The series of online workshops organised by 4TU.HTM entitled *Artificial Intelligence in Materials Science* for academic and industrial scientists attracted more than 75 participants on each occasion. A second online workshop in partnership with the LDE Centre for Sustainability entitled the *Joint Workshop on Circular & Sustainable Materials in 2050* was prepared for January 2022.

Educational activities

During the next few years the development of technology will be governed strongly by sustainability criteria. This will increase the importance of materials and materials science because the sustainable production, use and recycling of materials are at the heart of every technological design. 4TU.HTM is therefore seeking to cooperate with partners that also want to create awareness in this field. For that reason an educational initiative has been set with the 4TU.Centres Ethics & Technology and Energy, which has been given the name the 4TU.Responsible Sustainability Challenge. It is a multidisciplinary course for Master Honours students which is currently being developed by Programme Coordinators for the 2022-2023 academic year.

Other educational activities which were (partly) organised by 4TU.HTM in 2021 were the online Presenting Materials Science Skills Course for PhD Candidates and the M2i & 4TU.HTM Business Awareness Course for materials science PhD Candidates and postdocs, with a view to future careers in industry or science.

Differences in emphasis

4TU.HTM started the 2022-2025 phase with a new scientific director which saw Jilt Sietsma passing the baton on to Arjan Mol after seven years in the role. The new director is keen to change the emphasis slightly, in addition to focusing on the original priorities. For example 4TU.HTM will be focusing, in the coming years, on the junior materials science community, not only with a view to expanding the academic network, but also to build bridges with industry experts.

4TU.HTM is also going to continue to reach out to national materials science initiatives. In the context of national visibility and accessibility 4TU.HTM is expected to make a substantive and organisational contribution to the national materials science conference which has been announced for 2022.

A great deal of attention is to be paid to the online visibility of 4TU.HTM's materials science activities. In 2021 the milestone of 500 followers on Twitter was passed. This medium is being used in addition to the centre's updated website and LinkedIn group.

11 Humans & Technology

Scientific director	Dirk Heylen (UT)
Management team	Mark Neerincx (TU Delft), Wijnand IJsselsteijn (TU/e)

4TU.Humans and Technology (4TU.H&T) brings together the social and technology sciences around research into innovative forms of human-technology interaction. The primary aim of the centre is to work with researchers from the four universities of technology and external partners to create *road maps* for research and funded programmes. In addition, the centre seeks to create a living ecosystem of consultation among academic partners, the business community and other organisations. A special focus has been placed on training young researchers in the multidisciplinary field from the beginning.

Research events

In February Minha Lee defended her thesis entitled 'Interactional Morality: Technology as Our Moral Mirror', an empirical research into the role which *social agents*, such as chatbots and humanoid robots, can play in shaping humans as moral beings. Lee's research was also picked up by the national media. [Erik Scherder interviewed the scientist](#) about her research into Vincent, a self-compassion chatbot. The HRI conference took place at the start of March and Minha Lee helped organise the workshop entitled [Robo-Identity: Artificial identity and multi-embodiment](#). In September the centre organised an online 4TU H&T Lunch talk during which Tony Belpaeme gave an inspiring lecture entitled [Towards autonomous social behaviour in robots](#). During ICMI2021 Hayley Hung and Catharine Oertel helped organise the workshop [Insights on Group & Team dynamics](#). The [4TU H&T Symposium Vulnerability](#) took place in December. The aim of the symposium was to develop a measuring instrument which can be used to design HCI technology for vulnerable groups.

4TU PhD Winter School

The 4TU H&T PhD Winter School took place in Delft in the first week of November. After months of preparation this fifth edition of the winter school was a huge success. It was attended by a group of 45 PhD students from a wide range of EU universities, varying from Enschede to Amsterdam and from Stockholm to Edinburgh. The event was organised by the new generation of H&T researchers who the 4TU centre has trained in recent years. During the winter school Bernd Dudzik defended his dissertation entitled 'Towards artificial empathic memory: accounting for the influence of personal memories in automatic affect prediction'.

The future

The 4TU.Humans & Technology centre was not included in the 4TU.Federation programme of activities for 2022-2025. It is now up to the young researchers who have been training and developed in recent years to meet the need for a network.

Scientific director	Mark van den Brand (TU/e)
Programme manager	Margje Mommers (TU/e)
Board	Marc Geilen (TU/e), Alan Hanjalic/ Kofi Makinwa/ Justin Dauwels (TU Delft), Suzan Bayhan/ André Kokkeler (UT), Bedir Tekinerdogan (WUR)

The aim of 4TU's Netherlands Institute on Research on ICT (4TU.NIRICT) is to bring together, position and prioritise all aspects of ICT research. In the very broad field of ICT, 4TU.NIRICT focuses on the interface between electrical engineering and computer science. This is why the centre encourages and facilitates interaction and collaboration in these areas, as well as in other disciplines. NIRICT aims to unite the ICT community and recognises and values the role of young scientists in the institutions. This all takes place by means of community building activities such as the annual *community day* and various *calls*.

Community and DEI funding

In 2021 a large number of ICT researchers met to find a way of reinforcing the community. One of the ways 4TU.NIRICT did this was via the call for 'Community funding'. In addition to this call 4TU.NIRICT has also set up the 'DEI fund' (Diversity, Equity and Inclusion) to create more diversity, equality and inclusion within the community. Both calls relate to small-scale funding up to a maximum of €k10 per project. In 2021 10 projects were financed and this made it possible to organise a large number of workshops, meetings and round table discussions. These initiatives also resulted in, for example, Master's theses, papers, videos and joint proposals.

Research Impulse and 4TU.NIRICT call 2021

Due to the ongoing pandemic many activities were cancelled and 4TU.NIRICT therefore decided to put out a further two calls halfway through 2021. In the 'Research Impulse call' (€k190) two projects were granted, namely 'FLOW: Measures of breastfeeding and infant sucking behaviour and Robots for pain management in children'. In the 4TU.NIRICT call 2021 ((€k44) five projects were granted, namely *Smart bikes, Human-centered sustainable IoT, Using Food Recommender Systems to Promote Healthy Choices, Dutch Touch and Deep continual learning*.

The aim of both calls was to support activities which help to reinforce the 4TU.NIRICT community. Detailed reports of all the projects are available on the website.

ICT.OPEN and facilitating Next Generation

Just as in previous years 4TU.NIRICT was a partner of ICT.OPEN, the biggest conference for the ICT research community in the Netherlands, which took place online this year. 4TU.NIRICT aims to help the young generation and, for that reason, ICT Next Generation (ICTng) used financial support from 4TU.NIRICT to participate in the panel discussion which was part of the main programme. Work was started on a summary of the results of the survey entitled 'Perceptions of Academic Leadership among the Dutch academic ICT-community' which was distributed in the summer of 2020 in cooperation with ICTng. In order to involve the young generation of ICT researchers in 4TU.NIRICT the MT was expanded to include two new members to represent them, namely Suzan Bayhan and Justin Dauwels.

Looking ahead

In 2022 4TU.NIRICT wants to focus more on strengthening the connection between Electrical Engineering and Computer Science and on implementing the more ambitious mission and vision. The call for Community and DEI funding is to be adjusted. The aim is to fund a number of large projects, rather than numerous small ones. In 2022 a new initiative is to be started by inviting ICT researchers to give a pitch about their research during the 4TU.NIRICT board meetings in order to gain a better overview of all the research being carried out within the faculties.

13 4TU.ResearchData

4TU.ResearchData	Marta Teperek (Director) Madeleine de Smaele (Repository Manager), Paula Martinez Lavanchy (Carpentries Member Coordinator), Egbert Gramsbergen (Data Engineer), Ardi Nonhebel (Technical Team Lead), Jan van der Heul (Data Curator), Eric Rumondor (Data Curator), Connie Clare (Community Manager), Eirini Zormpa (Trainer), Deirdre Casella (Communications Advisor), Kees den Heijer (Senior Developer), Roel Janssen (Developer)
TU Delft	Irene Haslinger (Director, TU Delft Library), Alastair Dunning (Head of Research Services)
TU/e	Iza Witkowska-de Koeijer (Team Lead Research Data Management), Floor Luub (Data Steward)
UT	Marjolein Drent (Director, UT Library), Maarten van Bentum (Data Librarian)
WUR	Hubert Krekels (Director, WUR Library), Hilda van der Pol (Data Librarian)

Originally a data collection of hydrological measurements, 4TU.ResearchData has evolved into the largest data archive of its kind in the Netherlands. 4TU.ResearchData was established in 2010 as an initiative of three universities of technology (Delft, Eindhoven and Twente). The mission is to guarantee the accessibility of science and technology research data during and after completion of research, thus enhancing the quality of the research.

A recap

2021 was a year of community building and growth for 4TU.ResearchData. Researchers and research-supporting professionals are now working together on activities relating to FAIR data, including thematic *community calls*, workshops and training courses and [joint project proposals](#). [The Community](#), which was launched in 2020, now has well over 145 members.

The consortium has decided that it will continue to work on promoting and supporting FAIR data practices. This effort, in combination with close involvement of the members in [discipline-specific activities](#), makes it possible for 4TU.ResearchData to play a leading role in promoting national and European FAIR Data agendas.

Further expansion of the Community continues to be a priority, with the aim of gaining a better understanding of the discipline-specific needs of researchers and to keep up to date with evolving FAIR data trends and practices.

Expansion

In 2021 agreement was reached regarding Wageningen University & Research joining 4TU.ResearchData as from January 2022. The disciplinary expertise of WUR will benefit the centre, particularly in the field of agricultural, animal and plant science. This membership means scientists at Wageningen University will now also be able to use all services, such as free publication of 5GB of research data, access to community and technical support and advice.

Looking ahead

In 2022 work will continue on strengthening the position within the domain of technology and natural science, the cooperation with [Research Data Netherlands \(RDNL\)](#) and [National Programme Open Science](#) partners and an [internship programme](#) is to be started up.

14 Centre for Engineering Education

Director	Perry den Brok (WU)
TU Delft	Marcus Specht (leader), Remon Rooij (leader), Renate Klaassen (programme coordinator), Tanja Emonts (communication)
TU/e	Birgit Pepin (leader), Caroline Vonk (programme coordinator)
UT	Cindy Poortman (leader), Chris Rouwenhorst (programme coordinator)
WU	Emiel van Puffelen (leader)
Advisory Board	Kristina Edström (KTH Stockholm, chair), Marc de Vries (TU Delft), Ines Lopez (TU/e), Nieck Benes (UT), Erik Heijmans (WU), Ellen Siebers (Student UT)

The 4TU.Centre for Engineering Education (4TU.CEE) encourages innovations and research in engineering education. It does this by linking innovation in teaching to research, strategy development and international cooperation. The centre seeks to bring together lecturers and researchers from each participating university for each activity. The spectrum of projects and activities runs from a range of short innovation projects to doctoral programmes of longer duration. Connection to international experts and relevant literature is an element of the 4TU.CEE approach.

Strategic Plan

In 2021 4TU.CEE adopted its new [strategic plan for the period 2022-2025](#). Key themes during the coming period are: (1) entrepreneurial learning and academic entrepreneurship, (2) educating for responsible engineering or the ethical and responsible engineer, (3) ICT enhanced education and the digital literate engineer, (4) challenge based learning and (5) teaching excellence in engineering education.

The [Progress report 2019-2021](#) provides a nice overview of theme projects and benefits from the past strategic period. A fixed element is 4TU.CEE's overview of education innovation projects, namely the [4TU.CEE Innovation map](#). This was expanded to include 274 projects and 397 contact people in 2021. The upward trend in the online visitor numbers was continued.

In 2021 a total of 12 PhDs were appointed to the 4TU.CEE, of which two obtained their doctorate in that year, while a total of 16 postdocs worked on projects. In 2021 4TU.CEE researchers published a variety of documents, namely 5 research reports, 12 articles, 10 conference papers, 2 dissertations and 2 medium-related contributions. A variety of workshops and webinars were given, with visitor numbers varying from between 20 and 65. A seminar series was also set up together with the KU Leuven and the University of Western Australia for engineering education PhD Candidates, named 'Practise'.

The pandemic and education

The 4TU.CEE also published a [white paper](#) on research into education at the four TUs during the pandemic and organised a webinar during which the findings were presented and discussed. The results reflect an emerging theme on the importance of the welfare of students and employees within the total education system.

Challenge-Based Learning

The 4TU.CEE webinars on Challenge-Based Learning (CBL) also attracted a great deal of attention. A first series of four sessions feature the experiences with CBL at each of the four universities, after which Annette Kolmos from Aalborg University talked about experiences in Denmark, while a new series of research into CBL was started during a sixth meeting that will be the focus in 2022.

Initiatives have been started and will continue 2021 on the topic of 'ICT enhanced education'. In the UNCAGE project (TU Delft) *conversational agents* are being developed to support students in the development and training of study skills and for well-being monitoring. The use of new tools in education is being monitored at the WUR.

A start has been made on the issue of 'Entrepreneurship in engineering education' in the form of an inventory of *good practices*. A new doctoral candidate and postdoc will increase the focus on this issue during the coming strategic period.

15 Centre for Resilience Engineering

Scientific director	Tina Comes (TU Delft)
Managing director	Stephanie Hessing (UT)
Management team	Bas Jonkman (TU Delft), Geert Jan van Houtum (TU/e), Joanne Vinke-de Kruijf & Andy Nelson (UT), Miranda Meuwissen (WUR), Tatiana Filatova (DeSIRE/TU Delft)

The 4TU.Centre for Resilience Engineering (4TU.RE) is the knowledge centre that develops, applies and disseminates knowledge, methods, and techniques in order to make societies more resilient. 4TU.RE focuses on *engineering solutions* (technical solutions and system designs) in interaction with social-ecological systems. This report complements the annual report of the *HTSF DeSIRE (Designing Systems for Informed Resilience Engineering)* Programme.

In 2021 4TU.RE, together with the sponsored deans, the strategic advisory board and the research steering committee, held constructive discussions on how to perpetuate the work and ambitions of the centre and the associated DeSIRE.

Growing community

The strategic partners, represented on the board but also via the network in the various large and medium-sized municipalities, are actively involved via meetings and activities. External stakeholders (such as IBM) also help the younger tenure trackers via personal mentoring and introduction within their network.

Awards

In 2021 members of 4TU.RE were awarded research projects and subsidies both individually and in partnerships. One good example is the JOIN-Rise project on STEM education, which is one of 4TU.RE's priorities.

RE Academy

In 2021 the Open Education Platform's SURF project was formally completed, although work is continuing on the further dissemination of the platform materials with an active delegation of TTs. The community supports the mission to strengthen resilience engineering education through tailor-made courses, of which the content is shared (inter)nationally via this platform.

Network

Cooperation with colleagues is not only taking place within the individual bodies, but also at a broader national level (Zwolle, a cooperation of Security Regions and the VRU in particular, Limburg, etc) and also the sister institutes with similar, but complimentary, objectives such as the *Delft Climate Programme*, *Delta Future Labs*, the *Centre for Disaster Resilience* (UT) and the *Disaster and Pandemic Preparedness Center* (EMC/EUR/TU Delft). A Quick Scan is being worked on with the AMS institute.

At international level, cooperation is taking place on preparing the FSR-2023 event (Singapore, Stevens US and ETHZ), as well as with Texas A&M on coastal resilience, while regular consultations are held on cooperation in education and there are shared platforms with Turku (Finland) and the Resilience Academy in Tanzania. In 2021 4TU.RE was also approached and asked to participate in bodies such as ACRE, Safety Delta Nederland, CoP climate robust high-elevation sandy grounds and other parties.

Food and agricultural resilience is an important emerging theme within the centre and we were therefore proud of the fact that steering committee member Andy Nelson was invited to take the scientific lead on the '2021 FAO *State of Food and Agriculture report on food system resilience*'.

Visibility

A growing number of interested parties (more than 1,400) now receive the four newsletters every year and plenty of information is being shared with an ever increasing group of people on social media channels and LinkedIn.

During the floods in Limburg the urgency of resilience engineering became ever more apparent and many of the members appeared in public in the media.

16 Stan Ackermans Institute

Director	Paul Koenraad (TU/e)
Coordinator	Ben Donders (TU/e) (also coordinator for TU/e)
Board	Ariana Need (UT), Andrea Ramirez (TU Delft), Wouter Hendriks (WU)
Coordinator for Delft	Pieter Swinkels
Coordinator for Twente	Hans Voordijk
Coordinator for WU	Claudius van de Vijver

The Stan Ackermans Institute (SAI) is the banner under which the designer programmes at the universities of technology in the Netherlands are presented to potential trainees and businesses. Graduates receive the degree of Professional Doctorate in Engineering (PDEng).

Degree programmes

TU Delft has four active programmes, the University of Twente five and TU Eindhoven nine, of which one had to stop in 2021. Plans are being made to restart this programme. The University of Wageningen has announced that it is also going to introduce a PDEng programme in 2022 called Designs of AgriFood and Ecological Systems. SAI is in contact with the University of Groningen where there are also plans to introduce design programmes.

The total intake to the programmes has increased slightly from 162 to 168 and the number of graduates has declined from 146 to 135. An overview of intake and graduation figures by programme and institution is provided in the table in this section.

SAI has acquired funding from the Top Sector High Tech Systems and Materials (HTSM) and Chemistry. Businesses that are paying for the technological design project are offering the trainees financial support amounting to approximately € 20 per project during the second year of their programme. The idea is to maintain the number of projects during the coronavirus period. HTSM supported six projects at the TU/e and one at the UT, while Chemistry supported one project at TU Delft.

Organisation and PR

The make up of the board of SAI changed on 1 January 2021 and its members now include the deans of the Graduate Schools of the four TUs. The board is chaired by the dean of TU/e. The board assesses the macro efficiency of new programmes, while the CCTO focuses on the guaranteeing quality.

The SAI uses its website, brochures, and social media posts to promote itself. To recruit potential trainees the SAI also attends business days at the four universities of technology and this year a group of trainees has been formed, known as the PDEng ambassadors, to support PR activities. In 2021, a brochure was published containing a selection of design assignments completed by trainees. This was a special edition to celebrate the 35 year anniversary of the technical design programmes and the SAI's 15 year anniversary. Unfortunately the symposium which was intended to accompany this brochure had to be postponed due to the ongoing pandemic.

PDEng to become EngD

Due to the plans of the universities of applied sciences for a third cycle with the working title 'Professional Doctorates', 4TU decided to change the name Professional Doctorate in Engineering (PDEng) to Engineering Doctorate (EngD) as from 1 September 2022 in order to emphasise the academic level of the programmes and to avoid confusion with similar programmes at the universities of applied sciences. The aim is to anchor the EngD degree in a later stadium in the Higher Education and Research Act [Wet op het hoger onderwijs en wetenschappelijk onderzoek].

Overview of intake and degree certificates issued for design programmes 2016-2021

	2016		2017		2018		2019		2020		2021	
	Degree certificate	Intake	D	I	D	I	D	I	D	I	D	I
Eindhoven University of Technology												
Process and Product Design (PPD)	19	28	23	28	30	21	26	22	19	22	20	24
Information and Communication Technology (ICT) ²	14	10	3	12	10	5	8	5	8	6	3	8
Logistics Management Systems (LMS) ³	7	10	4	0	8	0	1	0	0	0		
Mathematics for Industry (MI)	14	0	5	0	0	0	0	0	0	0		
Software Technology (ST)	15	20	16	17	20	18	15	19	16	17	18	19
Design and Technology of Instrumentation (DTI)	10	9	6	9	9	0	6	0	1	0		
Architectural Design Management Systems (ADMS)	1	0	0	0	0	0	0	0	0	0		
User-System Interaction (USI)	14	13	18	0	10	1	2	1	1	1		
Automotive Systems Design (ASD)	11	15	14	14	14	14	13	15	13	16	13	16
Smart Energy Buildings & Cities (SEBC) ⁴	8	6	8	13	1	12	15	9	10	23	9	13
Clinical Informatics (CI)	11	13	10	13	12	13	10	14	12	14	10	11
Qualified Medical Engineer	6	7	0	5	6	7	5	4	7	7	4	6
Data Science (DS)		11		20	9	20	16	25	19	12	21	16
Total	130	142	107	131	129	111	117	114	106	118	98	113
TU Delft												
Process and Equipment Design (PED)	9	9	8	13	10	10	12	13	7	9	6	7
Bioprocess Engineering (BPE)	10	8	7	7	8	7	7	7	6	7	7	7
Comprehensive Design in Civil Engineering (CDCE)	1	0	0	0	0	0	0	0	0	0		
Chemical Product Design (CPD)	6	7	7	6	9	8	6	8	6	6	6	5
Civil & Environmental Engineering					0	5	0	6	2	5	4	6
Total	26	24	22	26	27	30	25	34	21	27	23	25
Twente												
Energy and Process Technology (EPT)	3	11	4	6	9	12	6	10	7	5	6	6
Robotics	4	5	2	4	4	3	2	1	4	1	1	7
Civil Engineering (CE)	3	7	4	2	4	7	6	7	5	6	4	6
Healthcare Logistics	0	0	0	0	0	0	0	0	0	0		
Maintenance	0	9	1	4	8	7	2	2	3	4	3	3
Business & IT								0	0	1		8
Total	10	32	11	16	25	29	16	20	19	17	14	30
Total, 4TU	132	177	129	185	169	154	166	198	140	173	181	170

² New name: Design of Electrical Engineering Systems

³ New name: Industrial Engineering

⁴ New name: Smart Buildings & Cities

17 High Tech for a Sustainable Future

With the award of a total of 22 million euros to five research programmes on the theme of *High Tech for a Sustainable Future*, the 4TU.Federation has given a huge boost to research and education in the field of sustainable technology. As a result the four universities of technology are taking the lead in creating significant impact on challenges facing society in the long term. The four universities of technology made this sum available in the context of the profiling budget intended for research that contributes to the *Dutch National Research Agenda (NWA)*. The research proposals fit the focus areas of the government's Top Sector policy, the NWA and the UN's Sustainable Development Goals.

17.1 DeSIRE

Programme coordinator: Tatiana Filatova, TU Delft

The purpose of the *Designing Systems for Informed Resilience Engineering (DeSIRE)* programme is to build up a flourishing resilience engineering community. In that capacity, DeSIRE serves as the initiating basic concept of the 4TU.Centre for Resilience Engineering. To develop solutions in complex socio-technical environment systems, different fields and disciplines should be interconnected, both inside and outside the academic world. Many of 4TU.RE's external stakeholders are therefore closely involved in the activities of the ever expanding DeSIRE community. DeSIRE now funds 17 tenure trackers (TTs) and 19 postdocs across 14 faculties. In view of the multidisciplinary capacity, the DeSIRE scientists are active both in the so-called thematic working groups (cities, water, agriculture, energy, transport networks and decision-making in uncertain conditions) and jointly.

Research

One of the research areas which gained momentum in 2021 is the resilience of food systems. Work is being done in several of the affiliated research groups on the transformation of agricultural and logistical systems in order to guarantee food resilience and security. In 2021 three new colleagues were appointed and several TTs are working on papers and research proposals on this theme at the TU/e.

In total 8 new PostDocs started in 2021 and the last 7 new DeSIRE PostDocs were appointed at the beginning of 2022. The DeSIRE members also turned out to be extremely productive in terms of publications in 2021 with 52 papers being published, including as contributions at international conferences. The TTs were also involved in at least 23 (new) PhD appointments in 2021 and 18 awardshave been made, both individually and within a partnership.

Education

The DeSIRE community is partly behind the new 'resilience thinking' of the generation of engineers currently being trained. DeSIRE is designing new courses within numerous disciplines into which resilience is incorporated as a basic design principle. DeSIRE is helping to fulfil the current and evident need for resilient STEM systems.

The community believes in sharing knowledge and that is why a great deal of time is being spent on the continued roll-out of its own Open Education Platform, where DeSIRE and 4TU.RE offer, customise and explain various learning materials to internal and external partners that are keen to incorporate the modules into their education programmes. Public institutions are also enjoying being able to use this option as shown, for example, by the extreme popularity of the RElastiCITY game.

In total the DeSIRE Community is involved in more than 41 educational activities (courses, supervising MSc/BSc students, workshops, etc), outside the contributions to the SURF activities on the Open Education Platform.

Growing external network

In October the DeSIRE community went on a two-day working visit to Zwolle where other partners were also welcome in order to work together with the TTs and PDs on urgent local issues. For example, the Utrecht Safety Region, WDO Delta, Havengebied Hengelo and the NOVI region with the municipality of Zwolle were also in attendance. This meeting turned out to be inspiring for both the scientists and the external stakeholders and resulted in several follow-up meetings and new projects.

Together with young KNAW members, DeSIRE organised a workshop on the new Recognition and Rewards. All TTs also provided input on this subject and a corresponding report will be submitted to the directors of 4TU.Federation in the spring of 2022.

The members of the DeSIRE community are frequently asked to contribute to events and meetings (in 2021 more than 89 times) and are collaborating on various subsidised projects with external partners (more than 14 projects).

The communication department has been reinforced and is extremely active in social networks in order to keep our broad and interested community actively involved. Every three weeks the communication department organises a DeSIRE seminar in collaboration with the working groups which results in a great deal of valuable interaction and discussion between the participants.

Internal cohesion:

The DeSIRE thematic working groups which cover the domains of *Cities, Water, Agri, Energy and Logistics* are to be supplemented by methodological and other transdisciplinary partnerships, such as the monthly meetings of the *Urban, Water* and *Decision Making* working groups.

A delegation of 8 DeSIRE TTs is involved in work on the scope and content of the open Resilience Academy and the platform.

17.2 Plantenna

Programme coordinator: Peter Steeneken, TU Delft

The Plantenna programme focuses on the heavily intertwined problems of climate change, air pollution and food shortages. In view of the growing world population and increasing urbanisation, these are issues that are set to intensify. A key component of the programme is the development of sensor technology that will collect information within plants about the condition and productivity of crops. By linking together plants equipped with this technology in networks – an 'internet of plants' – the information that is collected can be used to monitor the climate and weather and increase crop yields through more efficient fertilisation and irrigation.

Sensor technologies

Important steps are being taken as regards the various Plantenna sensor technologies in 2021. For example an ultrasound remote sensor has been developed which can monitor plants' vascular systems in a non-destructive way. This method was recently validated in greenhouses on a wide range of crops and a Netherlands Enterprise Agency (RVO) Technology Tech Transfer (TTT) grant was secured which has enabled a feasibility study to be carried out into the commercial exploitation of this technology.

A near infrared sensor has been developed to measure the dehydration of leaves. A special microscopic technique has been used to study the dynamic behaviour of stomata (pores in the epidermis of leaves) in fluctuating light conditions. Tests were carried out using radio frequency (RF) signals to determine the health of plants based on measured characteristics, both by means of a new measurement module for short-range characterisation in the field and by means of radar modules installed on drones. One highlight was the realisation of the so-called radiating RF mode in a plant which makes it possible to use a plant as an antenna. Electronic chips and modules have been designed which can read sensors.

Root system

The root system of plants has also been studied using a special installation which was used to measure the root growth and demonstrate that this was driven primarily by the vertical distribution of moisture in the soil. An article on this subject has been submitted to the *Hydrology and Earth System Sciences* journal. *Magnetic resonance imaging* (MRI) was used to study the uptake of nanoplastics by plants. The results may help gain a better understanding of the origin of nanoplastics in our food. In cooperation with the *FruitFrost project* measurements of the temperature distribution in orchards carried out. Surprisingly large temperature differences close to the ground were observed which will result in improved models which in turn will help prevent damage caused by night frost.

NWO Perspective

The NWO Perspective 'CropAlert' proposal, that was submitted in 2021 with a large number of the partners in the Plantenna project, was selected for inclusion in the second round. A complete proposal is going to be submitted in 2022.

A proposal has also been submitted for a 5 day Lorentz workshop which will bring together European experts to brainstorm on warning systems which would allow the early detection of plant diseases.

A plan has been drawn up to carry out a measuring campaign in a rented greenhouse in 2022 with a large number of the groups involved in Plantenna. This will involve the use of a wide range of new measuring techniques in a relevant environment. Combining measurement data would generate a better picture of plant development and how this is affected by climate. The aim is to use the results and measuring techniques to write a joint article with the Plantenna consortium.

17.3 Precision Medicine

Programme coordinator: Michel Versluis, UT

The aim of 4TU's *Precision Medicine* programme is to use *deep learning*, a special kind of artificial intelligence, and medical imaging techniques, to take diagnostics to a new level. In this way, the researchers involved in the programme aim to unlock more relevant medical information. This will enable a shift from a one-size-fits-all approach to a tailored, personalised approach and will help keep healthcare accessible and affordable in the long term.

Tenure trackers

Seven tenure track candidates – young and highly talented researchers – are working alongside twelve post-docs on this multidisciplinary programme. As well as having unique and independent academic profiles, the tenure track candidates are directly involved with improving and renewing teaching across the universities. They are teaching the academics of the future – physicists and mathematicians, biomedical engineers, and technical physicians.

Growth of the network

The network continued to grow in 2021. New PhD Candidates were appointed to NWO projects, including the Innovative Research Incentives Scheme and Perspective Programmes, the Dutch Research Agenda, as well as within the many start-up packages which the technical universities offer to their tenure trackers. Within the Precision Medicine Programme there is continuous alignment with the most important research themes in both the national calls (HTSM and LSH top sectors, mission-driven KIC calls, the large-scale research infrastructure NWO-RI, Gravitation Programme and Growth Fund) and the European agendas. Various activities are aimed at the regional *flagship* Programmes of the EU, including the recovery plans to mitigate the consequences of the coronavirus pandemic, such as REACT-EU. These activities are also strongly anchored within university hospitals and other leading hospitals. These strategic partnerships are also resulting in the natural involvement of policymakers, care insurers and manufacturers of medical equipment.

Hubs

The routes to interdisciplinary cooperation run directly past the 4TU hubs. A large number of researchers in the 4TU consortium, including some TTs, have part-time positions at university hospitals. Conversely, clinicians within the programme have part-time positions within the four TUs. The cross-pollination between various disciplines (in particular imaging technology and imaging data) on the one hand, and between the four TUs on the other, takes place via the key lines of exchange between the programme's PhD Candidates. Cooperation is, for example, taking place in the field of contrast ultrasound (UT-TU Delft), CMUT transducer technology (TU/e-TU Delft), multi-parametric US and MRI (UT-TU/e), and neural networks for quantitative MRI (WUR-TU Delft). At the same time the European and international network is also growing with new collaborations in Paris, Sophia Antipolis, Stanford, Case Western and Toronto.

Milestones

In 2021 encouraging steps were taken within the seven tracks of Precision Medicine. It was demonstrated, for example, that the location of contrast microbubbles can be determined with a resolution improvement of up to 70 times compared to standard ultrasonic imaging.

Researchers from Twente and Delft are developing a joint simulation framework for contrast-enhanced ultrasound. The simulator takes account of vascular geometry, flow dynamics and non-linear microbubble physics.

The MRI physics research in the Mars Lab has really taken off since the infrastructural obstacles were resolved in 2021. Since then several very promising projects have been initiated. An [interesting tech talk](#) on the importance of the work of tenure tracker Sebastian Weingärtner (TU Delft) in the eyes of cardiologist (Thomas Treibel of University College London) was published on the 4TU website.

17.4 Pride and Prejudice

Programme coordinator: Aarnout Brombacher, TU/e

The aim of Pride and Prejudice (P&P) is to gather new scientific knowledge and innovative technology that can be used to persuade people to adopt healthier lifestyles.

In this HTSF programme real-life monitoring via sensors (food consumption, physical activity and health parameters) is combined with the development of design interventions at different levels of the system (person, group, society) and with the evaluation of the effectiveness of these combined interventions.

Next steps

At the start of the year, the P&P Tenure Core Team organised a research day with all consortium members to map out the research themes and activities within the P&P consortium and identify follow-up steps for the final part of the programme and thereafter. It became clear that a broad spectrum of projects, divided across the dimensions of sensing, monitoring and intervention are active in the food domain. Opportunities were also found to expand research activities into the domain of physical activity, as well as the combination of exercise and nutrition, for example through lifestyle interventions. This led to the creation of a variety of small and larger collaborations in order to attract funding for further research and to continue building on the research results within P&P.

4TU.NIRICT

P&P researchers jointly managed to obtain a 4TU grant via the 4TUs' NIRICT centre, namely for *FLOW: Measures of breastfeeding and infant sucking behavior*. This project was successfully completed in the autumn of 2021 and led to preparations for a follow-up proposal by the researchers involved.

The research proposal entitled *Promoting physical activity through self-experimentation in cardiac rehabilitation patients* (TU Delft in collaboration with ErasmusMC and Capri Revalidatie) was awarded by TU Delft Sports Engineering Institute and TU Delft Health Initiative 2021 in the call entitled 'Technology that makes people move!'.

Education

Most teaching activities on the P&P programme involve the supervision of final year students. This type of education enables a bridge to be built between the P&P research and the educational activities. For example, WUR and UT are supervising a Master's student who is studying strategies which stimulate people to make healthier, vegetarian choices in restaurants. Another Master's student was supervised by the TU/e and WUR during their study of the ecosystem of breastfeeding within the FLOW project. Besides the supervision of students, a number of courses are being developed at the interface between nutrition and exercise fields, for example *Experience, Motivation and Behavior* (Bachelor IO TU Delft), *Product Use, Understanding and Experience* (Master's IO, TU Delft), and *Design for Behavior Change* (Masters IO, Computer Science, Communication Science). In addition, the knowledge developed by P&P research is being integrated into courses offered to students in the design curriculum.

Valorisation

A two-day event was organised during the *Dutch Design Week '21*. The first day was used to demonstrate the research carried out within the consortium with the première of the P&P film, which was intended to celebrate the results achieved and showcase the consortium members involved. A panel debate also took place with senior researchers from all four TUs and MMC Eindhoven on the subject of 'Designing out inequality: Pride and prejudice in design of technology for chronic disease prevention'. The second day started with a *Science Slam* competition to select the best research pitch by junior P&P researchers.

Publications

The consortium members published a variety of articles. Mailin Lemke and Roelof de Vries even won the 'Outstanding Article award' from Frontiers (computer science).

17.5 Soft Robotics

Programme coordinator: Herman van der Kooij, UT/TU Delft

Robots that operate among people need a 'soft touch'. The robots used in industrial production are extremely precise and fast, but they are also rigid. They are less suitable for safe physical contact with people or, for example, picking up foodstuffs that can be damaged easily. 4TU *Soft Robotics* seeks inspiration from nature, like the grip of a tree frog or the flexible tentacles of a squid. Biological knowledge, new control technology and innovative robot design go hand in hand here, with the partners in 4TU strengthening each other so that the Netherlands can command a leading position in this new field.

Active consortium

Within the consortium there are all kinds of initiatives which aim to help the members use each other's expertise and to put soft robotics on the map in the Netherlands. Both tenure trackers and postdocs regularly hold online meetings to learn from each other and to find ways to cooperate. The entire consortium, including partners and other interested parties met every two months in 2021. The tenure trackers and postdocs regularly give guest lectures in courses at the other universities, for example on Soft Robotics (WUR) and Haptics (TU/e). A solid foundation has been laid for lasting cooperation. In 2021 all the necessary preparations were made for a Winter School for approximately 30 European Phd students and a symposium for a wider audience in the field of soft robotics. Due to the ongoing coronavirus pandemic this event was moved to the summer of 2022.

Development of a demonstrator

The cooperation brought together the various models, control technology and (bio-inspired) sensors and designs to create operational soft robot installations. In 2021 a core team started work on the development of a joint *demonstrator*. This is an installation in which the various technology developed and other developments by the tenure trackers involved come together and demonstrate, in a variety of scenarios, the added value and possibilities offered by soft robots. The expectation is that the initial result will be presented in the autumn of 2022.

Milestones

The consortium received a great deal of media attention, for example in the NRC Podcast ([What an engineer can learn from an octopus](#)) and internationally via *Material distract* ([Attached to Mushrooms](#)). Consortium researchers also won a variety of prizes, for example the *Dutch Zoology Award* (Julian Langkowski) and *IEEE ToH Best Paper Award* (Irene Kuling), they gave many guest lectures and they have also been given the responsibility of organising a conference in the Netherlands (*WorldHaptics 2023*, Michaël Wiertlewski). Grants were also received, including the [Twente Crazy Research Call 2021](#) (Ali Sadeghi), [Bioengineering Institute Grant for research into shark skin](#) (Aimée Sakes) for the reduction in fluid drag and a grant for research into *shape-morphing catheter tips* based on topology (Aimée Sakes).

Published articles

The tenure trackers involved and other team members published a variety of articles, for example:

- Lussenburg K., Scali M., **Sakes A.**, and **Breedveld P.** (2022) [Additive Manufacturing of a Miniature Functional Trocar for Eye Surgery](#). *Frontiers in Medical Technology*.
- **Amador, G.J.**, van Dijk, D., Kieffer, R., Aubin-Tam, M.E., & Tam, D. (2021) [Hydrodynamic shear dissipation and transmission in lipid bilayers](#). *Proceedings of the National Academy of Sciences*, Vol. 118, No. 21, e2100156118.
- **Sharma, P.**, Saggiomo, V., Van Der Doef, V., Kamperman, M., & **Dijksman, J.A.** (2021) [Hooked on mushrooms: Preparation and mechanics of a bioinspired soft probabilistic fastener](#). *Biointerphases*, Vol. 16, No. 1, 011002.
- Murali Babu, S. P., Visentin, F., **Sadeghi, A.**, Mondini, A., Meder, F., & Mazzolai, B. (2021). [Sensorized Foam Actuator with Intrinsic Proprioception and Tunable Stiffness Behavior for Soft Robots](#). *Advanced Intelligent Systems*, 3(6), 2100022.
- Willemet, L., Kanzari, K., Monnoyer, J., Birznies, I., & **Wiertlewski, M.** (2021). [Initial contact shapes the perception of friction](#). *Proceedings of the National Academy of Sciences*, 118(49).

18 External relationships

As well as its many external relationships, the 4TU.Federation has specific agreements with several external parties. This section reports on the results of these agreements in 2021.

NEMO Kennislink

For more than 15 years NEMO Kennislink has been making scientific information accessible to a wide audience, specifically to secondary-school students and teachers. This is done using news items, background articles, files and multimedia across the breadth of science. The federation's support is also reflected in Kennislink's production figures in the area of Technology.

In 2021 NEMO Kennislink launched the theme 'Your data and you' [Je data en jij], the online equivalent of the 'Bits of You' exhibition, in the new exhibition space called 'De Studio', where NEMO is aiming to make the large transition themes more relevant to adults. The exhibition, the online theme and the corresponding peripheral programme showed how data and algorithms ensure that we all have a digital doppelgänger that influences our daily lives in all kinds of ways. A total of 167 articles were published in the field of 'Technology'.

Dutch CardioVascular Alliance

In a little over ten years, the chance of having an unforeseen heart attack or stroke will be a thing of the past. That is the aim of the *Dutch CardioVascular Alliance (DCVA)*, a new alliance that the 4TU.Federation joined in 2018. Twelve organisations, researchers and healthcare professionals in cardiovascular research are joining forces at national level. The idea is to be able to detect cardiovascular diseases earlier on and speed up the development of solutions and their availability (including evaluation) to patients. The joint objective is to realise a 25% reduction in the disease burden by 2030. To reach this goal DCVA expects that it will need at least 1 billion euros in the coming ten years for research, valorisation and implementation. The twelve partners are collaborating to bring the required manpower and resources together.

Science and Technology Registration Authority [Registerautoriteit Bètatechniek]

The 4TU.Federation is one of the co-founders of the Science and Technology Registration Authority [Registerautoriteit Bètatechniek]. The registration authority verifies the quality, transparency and comparability of the various professional registers in the fields of science and technology. The federation provides financial support to the foundation that carries out these activities.

Foundation for the Promotion of Science and Technology

With a financial contribution from the universities of technology, the Foundation for the Promotion of Science and Technology (STP) has implemented its programme in the context of the science and technology tournament OO Techniek, the Eureka Cup, the First Lego League Jr and the First Lego League. Funding was further scaled down in 2021 and additional steps were taken to relocate some of the activities.

History of Technology Foundation

The History of Technology Foundation (SHT) was established in 1988 on the initiative of the Royal Institute of Engineers in the Netherlands (KIVI) and the universities of technology. The SHT carries out groundbreaking work in the field of technological history. With financial support from the 4TU.Federation, SHT stimulates the history of technology and uses historical research and publications to illustrate the extent to which social and technical development processes are interwoven.

19 Visibility

The 4TU.Federation continued to strengthen its internal and external communication in 2021. The Techrede with the Drivers of Technology and the Dutch 4TU Impact Challenge was once again in the spotlight. In addition, the new series of 4TU.Binnenhof lectures proved to be a successful instrument in terms of updating MPs about a number of relevant technological developments.

Internal communication

The majority of 4TU centres and programmes have now appointed someone to be responsible for the visibility and communication of the respective centre or programme. That is creating a continuous stream of newsletters and interesting stories about 4TU cooperation. For example, the HTSF Plantenna Programme used a blog series to explain the types of research the team is involved in, the underlying techniques and how they are contributing to solutions in the field of agriculture and food, while in the Materials Science Stories series 4TU.HTM highlighted the diversity of materials science research, the contributions to the central challenges, as well as overarching themes such as cooperation and diversity.



Impression of 4TU messages on social media

External communication

In the 4TU.techtalks series 4TU highlighted a number of current themes which the four technical universities are working on together with business, the municipalities and parties like Achmea. These ranged from ethics in the data-driven world (4TU.Ethics) and efficiency in agriculture and horticulture (Plantenna) to the resilient city of the future (4TU.Resilience).

Specially for MPs 4TU combined the knowledge of the four technical universities in a series of seven Binnenhof lectures during which a professor, an entrepreneur and a student updated them on a number of subjects. These lectures ranged from a deepdive into medtech by biomedical scientist Monique Tabak, technical medicine student Robin Weijland and Demcon director Michiel Jannink to the ins and outs of the key technologies by high-tech systems professor Maarten Steinbuch, Sustainable Energy student Beatrix Bos and Ton Peijnenburg, Deputy General Manager of VDL-ETG.

In 2021 the students behind the Techrede joined forces under the name of Drivers of Technology. In consultation with politicians and business they started working specifically on a number of initiatives to accelerate social transitions, ranging from the 'Preven-tientje' in the care sector to the Hydrogen Board [Waterstofschap] to accelerate the energy transition. People could follow their progress via a vlog series, events like the InnovatieExpo, away days, the media and the Techrede itself.

There was also plenty of attention for the winners of the Dutch 4TU Impact Challenge. Among others Innovation Origins and De Ingenieur featured articles about the Hable start-up which won the challenge with the development of a Braille keyboard for smartphones.



Impression of 4TU messages on social media