Research Review
Mechanical Engineering
Eindhoven University of Technology

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Preface

This report summarizes the results of the Research Review of Mechanical Engineering of eleven research programmes of the Faculty of Mechanical Engineering at Eindhoven University of Technology. The review covers the research carried out in the period 2007-2012.

The Committee appreciated the thorough self-evaluation report provided by the Faculty, which contained valuable information and formed a very useful basis for an objective evaluation procedure. It acknowledges the openness of the management, Programme Directors and PhD students during the interviews and the constructive atmosphere of the discussions during the site visit. All representatives were willing to share their opinions and concerns in a very open manner.

The Committee hopes that the feedback provided in this report will be used judiciously in the quality assurance procedures of the Faculty and University.

As Chair of the Review Committee, I wish to thank the Committee members for their valuable contributions, for the time spent on this assessment and for the fruitful discussions in the meetings.

Last but not least, the Committee wishes to thank Annemarie Venemans, the Committee's secretary, for her assistance, enthusiasm, patience and wise counsel in the preparation of the visits and in the completion of the final report.

Prof. Bernhard A. Schrefler
Chairman of the Committee

1. The Review Committee and the review procedures

Scope of the assessment

The Committee was asked to perform an assessment of the research in Mechanical Engineering at Eindhoven University of Technology (TU/e). This assessment covers the research in the period 2007-2012. In accordance with the Standard Evaluation Protocol 2009-2015 for Research Assessment in the Netherlands (SEP), the Committee's tasks were to assess the quality of the institute and the research programmes on the basis of the information provided by the institute and through interviews with the management and the research leaders, and to advise how this quality might be improved.

Composition of the Committee

The composition of the Committee was as follows:

- Prof. B.A. (Bernhard) Schrefler (chair), Center for Mechanics of Biological Materials, University of Padova, Italy;
- Prof. P. (Paul) Van Houtte, Faculty of Engineering Sciences, KU Leuven, Belgium;
- Prof. A.E. (Erman) Tekkaya, Institut für Umformtechnik und Leichtbau, Technical University Dortmund, Germany;
- Prof. A.M. (Alexander) Taylor, Dept. of Mechanical Engineering, Imperial College London, UK;
- Prof. E. (Erik) Dick, Department of Flow, Heat and Combustion Machines, University of Ghent, Belgium;
- Prof. F. (Frank) Allgöwer, Institute for Systems Theory and Automatic Control, University of Stuttgart, Germany;
- Prof. W.A. (Wolfgang) Wall, Institute for Computational Mechanics, Technical University München, Germany;

A profile of the Committee members is included in Appendix A. Dr. Annemarie Venemans was appointed secretary to the Committee by QANU (Quality Assurance Netherlands Universities).

Independence

All members of the Committee signed a statement of independence to safeguard that they would assess the quality of Mechanical Engineering and its research programme in an unbiased and independent way. Any existing personal or professional relationships between Committee members and the programme under review were reported and discussed in the meeting. The Committee concluded that there were no unacceptable relations or dependencies and that there was no specific risk in terms of bias or undue influence.

Data provided to the Committee

The Committee received the following detailed documentation:

- Self-evaluation report of the unit under review, including all the information required by the Standard Evaluation Protocol (SEP), with appendices.
- Copies of key publications of the research programme.

The Committee was asked to evaluate a large number of research programmes, with a limited amount of time being available during the site visit. The intensity of the site visit was high, and though all Committee members as well as members of the TU/e staff were highly committed, the Committee is of opinion that at certain moments more time would have been beneficial to the assessment process. Nevertheless, it considers that it has obtained a good view of the work of all of the programmes and was able to assess them fairly.

Procedures followed by the Committee

The Committee proceeded according to the Standard Evaluation Protocol 2009-2015 (SEP). Prior to the first meeting on 13 May 2014, all Committee members independently formulated a preliminary assessment of the programme. The final assessments are based on the documentation provided by Mechanical Engineering, the key publications and the interviews with the management and with the leaders and researchers of the programmes. The interviews took place on 14 and 15 May 2014 (see the schedule in Appendix 3) in Eindhoven. In the same week, the majority of the Committee members also evaluated the Mechanical Engineering research programmes at the University of Twente. For this evaluation a separate report was produced.

Preceding the interviews, the Committee was briefed by QANU about research assessment according to SEP, and it discussed the preliminary assessments and decided upon a number of comments and questions. It also agreed upon procedural matters and aspects of the assessment. After the interviews it discussed the scores and comments. The final version was presented to the Department of Mechanical Engineering of the TU/e for factual corrections and comments. The comments were discussed by the Committee. The final report was published after formal acceptance.

The Committee used the rating system of the Standard Evaluation Protocol 2009-2015 (SEP). A note of caution when reading the evaluation: The SEP uses a five-point scale scoring system, which might give the impression that a ranking is possible between the different programmes based on the scores. The Committee came to the conclusion that such a ranking is not possible, because the programmes come from very different disciplines, each having a research and publication culture of its own. Nor can the scores be interpreted as a ranking of the programme with respect to other programmes in the same field; sufficient information about other programmes was not available to the Committee for such a ranking. The Committee decided that the scores should be interpreted according to the description of the meaning of the five numerical scores, which can be found in Appendix B of this report. However, it would like to point out that in using the five-point scale, it took into consideration the difference between the description in Appendix B and the actual impact of each of the points.

Technical disciplines, like Mechanical Engineering, are often societally relevant by nature. The Committee considers the quality of the research very important for its societal relevance and impact. Furthermore, it took into consideration, when assessing societal relevance, what strategy was used to increase the impact and societal relevance of the research.

2. Research review Mechanical Engineering at Eindhoven University of Technology

2A. Institute level

The Department of Mechanical Engineering (ME) is one of the nine departments of Eindhoven University of Technology (TU/e). It offers a Bachelor's programme and a Master's programme with five tracks.

The Departmental Board, appointed by the Executive Board of the University, consists of the Dean, the Vice-Dean and the Managing Director. The Dean is ultimately accountable for the overall management, while the Managing Director takes care of all matters concerning personnel and organisation, financial administration, services and accommodation.

The Department of Mechanical Engineering is fully discipline-oriented and can be divided into eleven research programmes:

- Control Systems Technology
- Dynamics and Control
- Manufacturing Networks
- Combustion Technology
- Energy Technology
- Process Technology
- Multiscale Engineering Fluid Dynamics
- Polymer Technology
- Structure and Rheology of Complex Fluids
- Mechanics of Materials
- Microsystems

Its mission is:

- To carry out long-term, generic, world-class research within the mechanical engineering domain on carefully selected topics that fall within the research profile areas of the university, and that match the technological interests of the high-tech, internationally oriented industry in the Netherlands and especially in the Eindhoven region.
- To realise an education and research programme with a balanced combination of fundamental and applied aspects, to provide industry with scientifically educated and application-driven engineers who are optimally equipped to address future challenges.

Assessment

Research at the Department of Mechanical Engineering of TU/e encompasses classical areas involving theoretical, numerical and experimental methods in heat transfer, control theory, solid and fluid mechanics as well as more novel applications of technology. Key areas are combustion and other energy conversion processes and the control of mechanical systems. Novel applications deal with material research over several length scales, microscale devices,

biomedical research for tissue engineering and medical instrumentation. This implies a wide variety of (sub)disciplines within one department. The Committee emphasizes once more that this makes it difficult, if not impossible, to evaluate the research programmes in such a way that the assessment – both qualitative and quantitative – of the programmes is comparable. The Department is developing fundamental new results in engineering sciences and makes the necessary knowledge available for ground-breaking improvements in technological applications. These developments also have immediate societal importance.

The mission to conduct both industry-oriented and scientifically oriented work suits a University of Technology and is also ambitious, according to the Committee. The topics of the research programmes are generally well placed and fit into an industrial environment. The availability of common laboratories is a great achievement, reflecting the ambition of the Department.

Quality and academic reputation

According to the self-evaluation report, the research of ME is internationally embedded and recognized. The world average citation impact of the ME department as a whole, according to the CWTS bibliometric studies, is up to 35% above world average (MNCS is 1.35) in the period 2002-2011. However, the MNCS indicator of the Department's publications showed a slight decrease from 1.40 in the period 2002-2005 to 1.26 in the period 2008-2011.

The number of journal publications has increased by an average rate of almost 10% per year over the last period. The self-evaluation report lists a number of researchers and publications that have contributed substantially to the scientific debate. Prestigious awards and grants have been won by a number of researchers.

Assessment

The Committee is impressed by the quality of the research carried out in the ME Department. The research performed in the programmes makes significant contributions both to cutting edge topics as well as innovative applications of new concepts and methodologies. Many programme leaders are very well known and internationally recognized as leaders in their field. The academic reputation of the department has been maintained during the assessment period at an excellent level even if it varies slightly between programmes. As far as the Committee could assess, the Department is nationally leading and very visible.

Resources

Table 1 shows the total number of staff of the ME Department. Until recently, all established research programmes consisted of a full professor and four to five assistant and/or associate professors, a part-time professor, a few technicians (shared with other research programmes), a secretary plus temporary scientific personnel (PhD students and postdocs). Younger research programmes tend to be smaller in size.

As can be seen in table 1, the tenured research staff has increased by 25% during the assessment period. The number of PhD graduates has almost doubled during the evaluation period.

Table 1: Staff embedded in the ME Department in fte

	2007	2008	2009	2010	2011	2012
Tenured staff	18	19.4	20.4	20.5	21.2	22.5
Non-tenured staff	14.6	16.3	17.3	18.4	23.5	21.7
PhD students	67.1	71.5	75.8	96.0	101.7	115.1
Total research staff	99.7	107.3	113.5	134.9	146.4	159.3
Supporting staff	15.4	16.5	17.1	17.1	16.9	16.7
Visiting fellows	10.0	5.6	2.5	4.6	6.2	11.2

Total funding rose from €18.9 million in 2007 to €23.2 million in 2012 (table 2). Direct funding decreased due to forced central cost-cutting actions, as the result of a reduction in direct funding at the university level. This reduction was partly compensated by direct support for new programmes by the University Executive Board. External funding from research grants and contracts almost doubled in the evaluation period (125% increase in research funding and 50% in contracts).

Table 2: Funding of the staff embedded in the ME Department

	2007		2008		2009		2010		2011		2012	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding (1)	12,146	64	11,818	62	12,650	58	13,436	58	12,408	56	11,411	49
Research grants (2)	2036	11	2171	11	2904	13	3405	15	3773	17	4570	20
Contract research (3)	4766	25	4941	26	6201	29	6485	28	5840	27	7258	31
Total funding	18,948	100	18,930	100	21,755	100	23,326	100	22,021	100	23,239	100

Note 1: Direct funding includes all funds acquired from the TU/e Executive Board.
Note 2: Research grants are grants from the national science foundations (NWO, FOM, STW) and ERC.
Note 3: Contract research is defined here as funds related to EU (FP6/7), Economic Affairs, LTIs and industry.

Assessment

The Committee concluded that the number of research staff has substantially increased over the review period. This is particularly true for PhD students. The slight decrease in direct funding is more than compensated for by the increase in the contract research as well as funds from research grants. Furthermore, the total funding has increased. There are some research grants from ERC, at both the starting and advanced level. This is impressive, but the Committee is of the opinion that grants at the intermediate level are missing. Attention should be paid to this aspect to assure a future with continuous opportunities for writing grant proposals.

The Committee understood from explanations given during the site visit that the department has developed a policy of not taking overhead financing from grants, so the full grant can be dedicated to research. It is very much in favour of this strategy. For example, this allowed the building of new facilities. From the lab visits during the site visit, the Committee concluded that the experimental facilities are excellent, and sharing the facilities is a good way of using them.

Productivity

The self-evaluation report provided information on the number and type of outputs of the Department's researchers. These data show that the number of journal publications has increased by an average rate of almost 10% per year over the last period, leading to a total increase of 64% from 2007 to 2012 (table 3). Other output declined over the period of assessment, like conference proceedings and patents.

Table 3: Main categories of research output in the ME Department

		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	128	166	165	175	148	205
	Conference proceedings	166	171	191	153	159	129
	PhD theses	28	24	22	19	29	33
	Books	-	1	2	5	1	4
	Book chapters	19	6	23	19	11	15
Total academic publications		341	368	403	371	348	386
Patents		17	14	10	8	6	3
Total research output		358	382	413	379	354	389

Assessment

The Committee is impressed by the overall quantity and quality of the research carried out in the Department of Mechanical Engineering. The scientific output of most of the programmes is excellent, though there is room for improvement in some. The field-harmonized and journal-harmonized results of the bibliometric study confirm this statement. In fact, only two programmes have an average normalized number of citations below the world average, while most of the remaining programmes are well above it.

It is understandable that the focus on increasing output in peer-reviewed journals has led to a reduction of other output. However, the Committee is of the opinion that the number of patents should be increased; it is actually rather low and shows a steep decline over the years.

Societal relevance

All ME programmes have links to societal institutions, and many members provide input for societal debates. According to the self-evaluation report, valorisation of the research is apparent from the increasing level of collaborations with industry within the different programmes, and this is also shown by the increase in external funding. Additionally, the department follows an active policy of initiating, accommodating and supporting spin-off companies and student teams.

Assessment

The socio-economic relevance of many parts of the research programmes is very good, and the research activities are in many cases embedded in various European and national programmes. The Committee is of the opinion that the number of initiatives of societal relevance could be improved. There are a couple of very good activities of societal relevance, but the number could be increased for some pressing topics like energy-related aspects. In particular, the direct research support to small and medium-sized industrial enterprises (SMEs) would deliver a short-term impact to the economic growth of the Netherlands and of Europe. A stronger link to manufacturing could be helpful in this context. The number of spin-offs is rather low, but the Department recently got on a good track. A department-wide strategy and support would help all programmes to actively, structurally and coherently translate their scientific work into societally relevant output and impact.

Strategy for the future

In order to assist the section chairs in their research and managerial tasks, the Department started a policy of appointing more personal professorships embedded in the research

programmes. Tenured senior staff members who meet the set criteria can be promoted to a professorship in that way. Furthermore, as some staff members will retire soon, the Department has started a procedure to attract new staff to fill the vacancies.

The Department addresses some major ambitions for the future, as documented in the self-evaluation report:

- ME will apply the knowledge in the Department to start more spin-off companies.
- ME will use the strong connections with industry to join more collaborative research funding initiatives at the EU level.
- ME will encourage and coach promising young faculty members to apply for personal grants which, if successful, will reduce the pressure on direct funding.
- ME will stabilise the output around levels of 2.5 students/scientific staff member, 1 journal paper and one refereed proceedings paper per year per PhD student on average to focus more on quality and to realise an increase in the citation indices.
- ME will focus more on the appointment of female faculty members.

Assessment
The Committee is of the opinion that the main ambitions and goals for the future are well chosen. However, it feels that a clear strategy for personal development is lacking. The Committee supports the idea of establishing personal chairs, since excellently performing staff members should be rewarded and talents need to be cherished. It is also a good policy, according to the Committee, to overlap professors close to retirement with newly appointed young professors. However, it is not clear who actually decides on the promotion and hiring strategy. Some professors will retire fairly soon, and although some steps were taken, the hiring procedure for their replacements has not yet led to results. A clear strategy for replacement, continuation or termination of important chairs should be put into place.

Encouraging promising young faculty members to apply for personal grants was well received by the Committee, but this should apply also to intermediate level faculty members (associate professors): for instance, there are no ERC consolidator grants at present.

Many of the programmes cite a lack of qualified PhD candidates to carry out the on-going research projects. The same programmes have extremely low numbers of female graduate students and female faculty. In those cases, the absence of women is not considered a potential cause of the problem by the faculty, nor the source of a possible remedy. The Committee learned that the female proportion of the Faculty in this Department at TU/e is well below 10%, and it strongly encourages the leadership of the Department to address this imbalance.

PhD training and supervision

In 2012, the Faculty had 115.1 fte of PhD students. In the assessment period, 90% of the enrolled PhD students finished their PhD successfully, 12% finishing within 4 years, 71% within 5 years, 7% within 6 years and 1% within 7 years. Of the remainder, 8% of the PhD student contracts have been discontinued, while 2% are not yet complete.

PhD students write a progress report after their first year, which is followed by a go/no go decision with respect to the following 3 years. The average duration of the PhD period is 4

years and 4 months, only slightly above the nominal 4 years and well below the national average.

The self-evaluation report states that PhD students can allocate up to 20% of their time to further education and professional development. Most inter-university courses are organised by the national graduate schools, offering course packages of 20-30 EC. Most PhD students in the department are embedded within such a school. In addition, the university offers a set of personal development (PROOF) courses (for example, Dutch, writing articles in English, career development, etc.). All courses are financed by the research programmes.

Assessment

The Committee learned during the site visit that there are no formal requirements for a training programme to be followed by PhD students except that a certain number of EC has to be taken. Most but not all PhD students are embedded in one of the existing Graduate schools. The level of all national inter-University courses offered by national graduate schools is not equal. The Committee is of the opinion that all PhD students should be embedded within a Graduate School. The institute/faculty should carefully select which Graduate schools are chosen in order to assure the highest level of training. Also, the suggested transition to compulsory graduate programmes to be set up for the next six years is regarded very favourably by the Committee. More information sharing between PhD students working on particular topics is desirable.

The success rate of PhD students is rather impressive. The quality of the PhD theses the Committee read was excellent. These theses have reference value for the topics dealt with.

2B. Programme level

2.B.1 Programme: Control Systems Technology

Programme leaders:	Prof. M. Steinbuch	
Research staff 2012:	32.0 fte	
Assessments:	Quality:	5
	Productivity:	5
	Relevance:	5
	Viability:	5

The mission of the Control Systems Technology programme is to develop new methods and tools in the areas of Systems Theory, Control Engineering and Mechatronics and to apply them in a wide variety of areas, most of which have industrial relevance. The research focuses on understanding the fundamental system properties that determine the performance of mechanical engineering systems and exploiting this knowledge to design the high-tech systems of the future. In particular, the research programme concentrates on performance-driven control and systems design, and develops robust and data-driven control theory, hybrid and networked systems theory, optimisation techniques and mechanical design principles aimed at high-performance motion systems, robotics, vehicle powertrains and the control of plasma fusion as application areas. The programme contributes to all three strategic areas of the department (research, education and industry) and leads the Smart Mobility area (connected cars and clean vehicles).

The programme is led by two full professors who decided to join forces and bring together two formerly independent programmes. This joining of forces has led to a further strengthening of already strong programmes and has to be complimented as being very successful. Both professors have an excellent international reputation and do complement each other very well. In addition, there is a strong cooperation between this programme and the Dynamics and Control programme (for example, joint labs).

Quality

Even when applying the highest international standards as a measure, the quality of the programme is excellent. The senior researchers have outstanding international reputations with a good international embedding and are considered leaders in the field. This is shown, for example, by the number of awards bestowed (including a VICI grant and two VENI grants), the number of invitations for plenary talks at major conferences, and the invitations to serve in leading editorial roles for major journals, to list just a few. The programme is able to acquire a very impressive quantity of external research funds that amounts to about 20% of the funding of the whole Mechanical Engineering department. The industrial funding is very high, especially when considering that parts of this funding do go into fundamental research. This shows the high quality perception and industrial relevance of the research being carried out. The number of competitive public grants has increased significantly (in part due to the VENI and VICI grants), and the relationship between public and industry funding must be seen as very healthy by now. The number and impact of the programme's publications (and patents) are substantial.

Productivity

The composition of the research areas is excellent, comprising both theoretical developments and application work. The different research areas do complement each other well and are still convincingly related to each other. The number of PhD students is very high, and the success rate for completing a PhD is excellent. The number of ME students choosing this direction (35% of the total) is even more impressive, but may lead in the long run to an undesirable imbalance between programmes. The programme leaders should think about ways to make the other programmes more attractive for students or to discuss a different allocation of ME staff to account for higher educational burdens.

As discussed above, the research funding level has been growing to a very high level and is well balanced. The academic output, visibility and impact are outstanding. It will be very difficult in the future to increase this level further and possibly even to maintain it.

Relevance

The research topics of this programme are up to date and relevant for basic research and for industry and society. The field of model-based control, identification and design of motion systems is especially well aligned with the needs of the regional industry. Other fields, and in particular robotics for care and cure, are future oriented and geared towards the needs of society. Hybrid and networked systems and the field of control of fusion plasmas are directed more towards fundamental research and have to be considered as very timely. The respective relevance of these fields can be seen from the strong industry funding and the successful spin-off companies that were initiated by the programme.

Viability

The forward-oriented research agendas, together with the very impressive labs, the obvious attractiveness of the programme for the best students, and the solid and diverse funding base form an excellent basis for the sustained development of this programme. The Department is encouraged to think about further ways to support the outstanding developments in this programme.

Conclusion

The Control Systems Technology Programme is characterized by an exceptional quality, productivity and relevance. Both fundamental research and applied research of industrial relevance are carried out on an international level. The researchers have an excellent international reputation. The combination of these points puts it in a leadership position worldwide.

2.B.2 Programme: Dynamics and Control

Programme leaders:	Prof. H. Nijmeijer	
Research staff 2012:	21.1 fte	
Assessments:	Quality:	5
	Productivity:	5
	Relevance:	4.5
	Viability:	5

The mission of this programme is to conduct high-level research in the area of dynamics and control, with the emphasis on modelling, analysis and control of mechanical and mechatronic systems. Nonlinear dynamics and control, acoustics and robotics are among its focal areas. Fundamental research is combined with numerical tools and supported by dedicated laboratory experiments. Teaching at the undergraduate and graduate levels, in the spirit of Humboldt, is a key integral part of the mission of the programme, to provide students with state-of-the-art knowledge and skills in dynamics and control. The programme is particularly active in the strategic areas of energy and smart mobility of the Department.

This programme is well aligned with the Control Systems Technology programme, with shared labs and many joint activities, like a joint yearly strategy meeting with all faculty, staff and students. Nevertheless, the need for separate programmes was clearly explained, and there is a convincing strategy for future development.

Quality

Under the leadership of Henk Nijmeijer, this programme has been developing into an internationally leading centre for research in the fields of dynamics and control. The combination of mathematically rigorous method development on a worldwide leading level with practical applications in the field of mechanics is unique. The number of publications in top journals, and especially the impact of these publications, is outstanding. All of the senior researchers are internationally prominent, which can be seen from the awards, external appointments, plenary and invited lectures, and invitations to serve on editorial boards they have received. In particular, the strong and dense international embedding of this programme is noteworthy. The outstanding quality of the research being conducted can also be seen from the many awards that students of this programme have received for their work and by the large number of former PhD students who have started successful university careers at other universities like ETH Zurich, KTH Stockholm or NTNU Trondheim. The programme also plays a strong role in the education of ME students (and of PhD students of control across the Netherlands) and continues to excel in this domain.

Productivity

Both the number of PhD students and the number of publications have been increasing over the past few years. The total funding has almost doubled since the last assessment, and the number of competitive public grants remains at a high level. The ratio between public and industry grants appears optimal. There is a very large number of excellent ME students who are choosing this direction and are well trained for continuing a career in industry or academia. Altogether, the productivity of this programme is excellent on an international level.

Relevance

The research topics of this programme are timely and of relevance for industry and society. The strong interconnection with industry has to be applauded and is one of the very strong points of the programme. Research areas are chosen to fit closely to the needs of industry, while at the same time stressing the necessity for fundamental research developments. Even though the research topics are very well chosen, greater emphasis should be placed on some newer directions in key development areas like energy, traffic, autonomous robotics, health or the environment to better acknowledge the developing societal needs of the future.

Viability

This programme has a strong research agenda, a solid funding base, outstanding international connections, excellent facilities and access to a large number of outstanding students. This combination should warrant success in the years to come.

Conclusion

The Dynamics and Control programme is highly successful and on a good track. The researchers are among the very top professors in the field worldwide and have an excellent international reputation. When taken together, there are very few places in mechanical engineering worldwide with a similarly impressive standing as this programme. The university and the department are advised to continue their strong support for this programme.

2.B.3 Programme: Manufacturing Networks

Programme leaders:	Prof. I.J.B.F. Adan	
Research staff 2012:	6.9 fte	
Assessments:	Quality:	4
	Productivity:	3.5
	Relevance:	4
	Viability:	4

The programme aims at managing the complexity of manufacturing systems through contributions from interdisciplinary research at the interface of operations research, engineering optimisation, control theory, computer science and design science. The research is focussed on four topics: Performance analysis to evaluate system performance in terms of throughput, flow times, timeliness and reliability, engineering optimization for multi-disciplinary and simulation-based design, controller design for networks and, finally, systems design to support systematic design and improvement of complex engineering systems. This programme is the successor to "Systems Engineering". The research strategy is based on the SEA concept: Science, Engineering, and Application. The science part reflects the fundamental research, and the engineering part refers to the development of software tools founded on this scientific basis. The application part of the research activities includes validation of the newly developed methods and tools in industrial applications and teaching.

Quality

Based on the multidisciplinary and system-oriented character of the research field, publications appear in a variety of journals of varying quality. The development of new methods leading to new software tools and languages has been recognized in the international community, as evidenced by the number of publications accepted in high-impact journals. The programme managed to acquire substantial research funding, with the NWO VIDI grant and public funding underlining the national recognition. Several researchers have editorial responsibility for international journals, reflecting the scholarly acceptance. The programme could improve even further by attracting more PhD students and by building continuity on the research input side.

Productivity

Journal publications have increased during the evaluation period from 46 academic publications in 2007 to 63 academic publications in 2012, but can and should be improved further. Almost half of the publications involved collaboration with other programmes. The balance between journal and conference publications is reasonable. The number of PhD students dropped continuously throughout the evaluation period. This is a worrying development. The SEA concept has to be reconsidered in this sense. External funding, like EU-funded projects, will hardly improve the scientific productivity. Setting clear goals on productivity and developing a strategy might prove to be effective.

Relevance

Industrie 4.0 (the high-tech movement of the German industry and academia, which promotes the computerization of traditional industries such as manufacturing; also called "the

internet of everything" in the USA) is considered the third industrial revolution in some parts of the world, and the heart of this movement is manufacturing networks. The industrial interest in and need for this research field are higher than ever. A stronger involvement of the 'Manufacturing Networks' programme in this field is inevitable. More focussing on real manufacturing systems would increase the impact of the programme in this emerging field.

Viability

The evolution of the programme since the last assessment has been successful. The new focus on manufacturing reflects the industrial trend. The strategic decision to appoint two professors with backgrounds in operational research and formal methods after the retirement of the former chair in 2011 will contribute to an increase in productivity and research quality. The programme has no laboratories except for didactic training stations. The new strategy to conduct MSc theses in industry is helpful, but should not be restricted to MSc studies.

Conclusion

This programme realised a successful shift of focus of its research goals. The new chair and professors will have to ensure that the research will be focussed on manufacturing in practice. Refocusing the programme while continuing the topics of the previous focus will reduce the impact of the programme. The spirit of Industrie 4.0 should be utilized more effectively by the programme. More PhD students could be included in the research work, especially for public grant projects, resulting in higher scientific productivity as well. Laboratories for manufacturing systems could support the validation of fundamental research and attract more industrial funding.

2.B.4 Programme: Combustion Technology

Programme leaders:	Prof. L.P.H. de Goey	
Research staff 2012:	18.5 fte	
Assessments:	Quality:	5
	Productivity:	5
	Relevance:	5
	Viability:	5

The Combustion Technology programme works under the premise that combustion will remain the main energy conversion process for the foreseeable future, if only because long-distance transport by land, sea and air will remain dependent on liquid fuels owing to their high energy density. Within this context, the traditional concerns of reducing emissions and increasing thermal efficiency form the focus of research in the context of new modes of burning (such as low temperature combustion and 'flameless' combustion) with the anticipation of novel fuel compositions, whether bio- or solar-derived. The programme develops mathematical models in the context of improving current and future combustion systems (internal combustion engines; small-scale domestic heat and power systems; gas turbines). As expected, the programme is extremely 'well founded' in terms of computer facilities and software.

As part of model development, the programme undertakes experiments to evaluate models: it is worth noting that the lab facilities are world-class, based on eight engine cells equipped with high-pressure burner setups, optical engines, advanced laser systems and a high-pressure, constant-volume vessel. There is thus a balance between fundamental and applied research work, with the emphasis recently being on the latter by strengthening the industrial network of and the innovation from the programme (two spin-offs). The team consists of one full professor, five assistant/associate professors and short-term appointments of part-time professors from abroad who are well-known experts in their respective fields. In addition, there is a shared programme of lab-support staff and contact and support from employees from the programme's spin-off companies.

Quality

The programme publishes in the highest quality journals and has chosen to highlight its activity under the themes of the (i) heat flux method to stabilise adiabatic flames; (ii) the Flamelet Generated Manifolds (FGM); (iii) future engines and their fuels; (iv) quantitative theory for the influence of flame stretch and curvature; (v) analysis and control of flame-acoustic interactions. Topics (i) and (ii) have generated great interest in the community, whether through the organisation of workshops or their use by industry and incorporation in commercial CFD codes. The citation of these two activities is also strong and, while very welcome, citation is more a metric of visibility rather than directly of quality per se. However, these two subjects are at the centre of current interest in the science of combustion, and there is no doubt that this programme has made an high excellent contribution.

It is gratifying in the context of 'quality' to note the strength of the reputation of the programme and of its members. Over 30 awards were cited in the submitted documentation, including the prestigious Simon Stevin Meester award, editorial positions with prestigious journals, visiting positions at well-known institutions overseas, the ability to attract high-

profile names to the part-time professorships in the Combustion Technology Programme and so on. In addition, the programme is a member of several well-known and active international research consortia.

Productivity

The output of the number of refereed articles fluctuates from year to year but, including SAE (Society of Automotive Engineers) articles, is well in excess of 25 per year for 6 tenured staff members, representing about 1.9 fte. Assuming that these articles were written by PhD students, and given that there are between 4 and 5 PhD students graduating per year, this represents a good average. The decision to publish more often in the SAE is understandable and, indeed, wise in view of the general strategy of the programme, even though the standard of the papers in that forum is somewhat variable. The focus on patents and spin-offs is also probably wise in terms of future assessments concerning the quantification of relevance and impact.

In 2012, the programme raised a very useful amount of contract research funding from industry (€495,000), representing about 30% of total funding (≈€1.7 million), and this is part of a desirable trend to increase the funding from 'valorisation' and projects fully funded by industry.

Relevance

Society's expectations for improved fuel conversion efficiency, lower emissions and preparedness for 'flexible fuel sources' are important problems and have been so for many years. The Combustion Technology programme has chosen subjects for research which are worth investigating: the foundation is the long-term fundamental research while retaining immediate relevance by cooperation with a network of companies on both precompetitive research as well as on more practical combustion systems. It is worth noting that two spin-off companies have emerged from the programme – a direct example of valorisation - with which the programme maintains close links. One qualitative criterion, which suggests that the programme's work is indeed relevant, is that it has been successful in maintaining long-term funding from its industrial partners and membership of industrial advisory boards. The programme is clearly active and sincere in its efforts to valorise its research and is one of the two programmes most successful in winning 8 STW (technology foundation of NWO) valorisation grants.

Viability

The subject matter of the programme, namely combustion technology, is likely to remain one of interest for the foreseeable future, and the funding for basic and applied research should remain adequate. The number and range of tenured staff are also well adapted to the research that the programme is performing: it is encouraging to learn that the programme is advertising for the vacant position on 'engine experiments', which is perhaps the one readily identifiable gap in the programme's range of expertise.

The difficulty in filling PhD and post-doc positions – as well as in finding female students – is not something that is unusual to this programme, unfortunately; the steps that the programme is taking to counter the problem are welcome, and we can only wish them success.

The laboratories are an important capital asset which depreciate each year; the sum of €400,000/year that the programme spends for investment is necessary and, as the self-evaluation report notes, is possible only through the programme's strong funding base. The need to maintain this in the face of the decline in the 'direct financing' budget has been met successfully so far, and the plans for the future are realistic.

Conclusion

This programme performs world-class research in combustion technology; it has been productive, has made a significant impact within the combustion community, and has been very active in finding viable, long-term research topics that serve the needs of society. The programme has chosen its topics carefully, it has tenured staff able to do excellent research in these topics, and it is established as viable. As always, the recruitment of able PhD and post-doc students is the ultimate 'rate-determining step' in quality, productivity, relevance and viability. Here, there are small clouds on the horizon, and the programme must concentrate on finding the means to continue the tradition of recruiting candidates who are well above average.

2.B.5 Programme: Energy Technology

Programme leaders:	Prof. D.M.J. Smeulders	
Research staff 2012:	13.1 fte	
Assessments:	Quality:	4
	Productivity:	4
	Relevance:	4
	Viability:	4

The mission of Energy Technology is to develop new methods and tools for the extraction, conversion, transportation, storage and use of energy, targeted towards producing highly efficient (sustainable) energy systems while mitigating the side-effects on humans, nature and the environment.

Quality

The Energy Technology programme published 76 refereed journal articles and 109 conference papers in the review period of 6 years. There was also involvement in books and book chapters. With respect to quality, the ratio of journal papers to the rest seems good. About 21% of the journal publications are in top-tier journals. The choice of the journals seems justified to the Committee. It includes some highly esteemed journals, with an average journal score (MNJS) of 1.08. The citation score of the research programme is rather low. An explanation by the programme given in the self-evaluation report is the re-orientation of the research topics which started in 2009. The Committee accepts this explanation and therefore judges the quality of the publications higher than what would be concluded directly from the mean citation score.

The Committee appreciates the re-orientation of the research lines into "enhanced thermal transport" and "small-scale energy systems", with an emphasis on the topics "thermal storage and conversion" (reversible sorption processes), "separation of gases" (condensation in expanding gas streams) and "cooling of microsystems". It understands that recently the topic of "hydraulic fracturing" (by means of numerical simulations) was added.

The staff members have international visibility, with activities in several international organisations. The involvement of the team members and their recognition on the scale of the country are clear. Further, the Committee appreciates the personalised training programme for PhD students, with its rather strict assessment.

Productivity

The productivity in terms of numbers of refereed journal articles is not poor, but not very high. It is about 2.20 per year per tenured track person (76 publications in 6 years for 5.75 persons). The obvious reason is the rather low number of completed PhD theses, i.e. 19 for the review period of 6 years. This means about 0.55 per year and per person of tenured staff. The official goal of the Department of Mechanical Engineering and the research programme is 3 PhD students per staff member, which means, theoretically, about 0.75 defended PhD theses per year and per staff member. An explanation may again be found in the re-orientation of the research topics. The number of PhD students increased in the last few

years to 16 at the end of 2013. This number is close to the target number of 17 according to the latter criterion. The conclusion is that the research programme has improved its efforts to collect research funds and recruit PhD students. The Committee judges that the productivity of the programme has not been optimal in the review period, but that the potential for a good productivity was reached by the date of submission of the self-assessment report. The fundraising in the latter half of the review period was sufficient to reach the target number of PhD students. Somewhat more than 50% comes from contract research. The Committee judges this as normal for the kind of research topics covered by the programme.

Relevance

The choice of the research topics "thermal storage", "separation of gases", "cooling of microsystems" and "hydraulic fracturing" is justified on the world scale and on the local scale of the Netherlands. The committee considers these topics to have high potential for the future societal relevance and impact of the programme.

Viability

The programme aims to further expand research on "thermal storage and conversion", "separation of gases" and "cooling of microsystems" and "hydraulic fracturing". The Committee agrees that this choice is well justified and constitutes a focus on a limited number of research topics. It is also clear that the funding of research on these topics is very realistic due to industrial interest in the research results. The Committee understands that the research on the last topic is supposed to contain a large proportion of numerical simulation, which will be done in co-operation with the Multiscale Engineering Fluid Dynamics research programme; this last programme reports in fact activities on crack propagation.

With respect to the acquirement of funding, the Committee understands the threat seen by the research programme in the tendency of funding agencies on the European level and on the Netherlands level to favour large research consortia working in a focussed way on a topic that is of immediate industrial relevance. It agrees with the proposed strategy to become a member of such consortia.

The objective of the research programme is to consolidate the number of PhD students to the current level of 19. The Committee agrees with this point of view.

Conclusion

The Committee judges that the research programme on Energy Technology has worked in a suboptimal way in the review period with respect to the quality of the work performed and productivity. It also feels that the research programme has improved in quality of research, in focus of research and in productivity during the review period (2007-2012) and that it has now reached a size that is viable. It agrees with the choice of research topics: three consolidated topics (thermal storage, separation of gases, cooling of microsystems) and the newer topic of hydraulic fracturing. It agrees with the plans to continue and strengthen research on the first three topics and to build up research on the fourth topic. It recommends, however, investigating a possible co-operation with the Multiscale Engineering Fluid Dynamics research programme on the topic of hydraulic fracturing. It agrees with the programme's strategy to become a member of large research consortia. It recommends that the programme pay attention to the quality and quantity of its publications. It also suggests

that the research programme work on its international visibility, but this can be easily achieved if the research programme succeeds in creating high quality in the chosen research topics.

2.B.6. Programme: Process Technology

Programme leaders:	Prof. J.J.H. Brouwers	
Research staff 2012:	9.7 fte	
Assessments:	Quality:	4.5
	Productivity:	4.5
	Relevance:	5
	Viability:	5

The Process Technology programme serves an industry that accounts for one-third of the gross national product of the Netherlands. Within this context, the programme combines experimental, theoretical and analytical methods to focus on fundamental phenomena that are important to Dutch industry in four areas: (i) Statistical Turbulence and Dispersion; (ii) Phase Transitional Flow; (iii) Rotating Fluid Flow; (iv) Sub-surface Flow (newly started research topic on the extraction of energy from the earth). The programme concentrates on the new technologies of rotational phase separation, wall de-sublimation techniques and condensed rotational separation. As expected, the programme is extremely 'well equipped' in terms of computer facilities, laser-based instrumentation and other specialised equipment as a result of investments in lab facilities in the period 2007-2012 which amounted to €955,000, partly funded by long-term loans from industrial partners. There is thus a balance between fundamental and applied research work, reflecting the fact that funding from public grants and contract research are almost equal in magnitude, when averaged over the six years: the output includes patents, knowledge transfer to industry, and products conceived and developed in-house.

Quality

The Process Technology programme publishes in above-average journals and has chosen to highlight its activity under the themes of (i) Statistical description of turbulent flow and dispersion; (ii) Phase transitional flow; (iii) Flow in rotating machinery. The first theme, which is clearly in the category of fundamental research, has found practical application in assisting the development of a subgrid model for large-eddy simulation of particle-laden turbulent flow. The second activity has led to publications in a wide range of journals, describing a correspondingly wide range of interesting phenomena, and has been extended to bioengineering applications. The third activity has (a) confirmed experimentally, for the first time, that forces can arise that lead to backward-whirling impeller; (b) ascertained the origin of damage in ship propulsion systems due to non-uniform suction flow; and (c) led to guidelines for the selection and operation of pumps to minimise damage to fish.

Despite the useful areas of activity chosen by the programme, the self-evaluation report notes that the citations are somewhat below average. The report goes on to explain that this is partly due to the fact that, despite the increase in the number of articles published in SCI journals from 2010 onwards, there is a lag of approximately five years for citations to build up and that the research communities in some of the fields of activity of the programme are small. The Committee agrees with this. Fortunately, the number of citations for part of the numerical work is relatively high.

In the context of 'quality', the Committee notes that all tenured members have been externally active and successful (e.g. advisors to well-known companies, institutions,

recipients of awards, membership of juries, publication prizes, invited presentations, editorships and so on).

Productivity

The output of refereed articles averaged about 11 per year (68 over the 6-year period) for 5 tenured staff members, representing about 2 fte. Assuming that PhD students wrote these articles and given that there are about 2.5 PhD students graduating per year, this represents a good average.

There has been a gradual increase in the number of publications. The cause of this welcome trend is not immediately apparent: the Committee hopes that the current level can be maintained in the future. In 2012, the programme raised a very useful amount of contract research funding from industry (€660,000), representing 66% of the total funding (≈€1 million), and this is part of the general ability of the programme to attract large sums from industry, with which the programme seems to have adequate links in terms of breadth and depth.

Relevance

Inevitably, and happily, the research of the Process Technology programme originates from problems identified by industry, which ensures that the output of the programme remains relevant. For example, the programme designed a heat exchanger that has become standard in domestic balanced ventilation systems, with energy savings of 600 m^3 of natural gas equivalent per year for a Dutch reference dwelling. A student has designed an airport Snow Sweeper - a device for compacting snow by a novel extruder - that is being evaluated at air force bases in the Netherlands and Finland. The Rotational Particle Separator (RPS) has resulted in patents and is being evaluated in the oil and gas industries. Condensed Rotational Separation (CRS), which enables the separation of gaseous mixtures by selective condensation, has a great potential as a compact alternative to the distillation column, and several industrial applications are under development. Additionally, the programme has produced guidelines for fish-friendly pumps, changed the legislation and design for biomass power plants in respect of particulate emissions, provided advice on endovenous laser ablation, and added to the International Atomic Energy Agency's capability in the early detection of possible misuse of nuclear material and technology. The recent award, by Shell, of €2,500,000 is further tangible proof of the value placed on the relevance of the output of the programme.

Viability

The subject matter of the programme, namely process technology, is likely to remain interesting for the foreseeable future, and funding for fundamental and applied research should remain adequate. The recent grant from Shell is directed to funding the infrastructure for (i) a new lab facility for subsurface geophysical flow studies, (ii) novel rheological materials for use in hydraulic fracturing of low permeability gas reservoirs, and (iii) novel hydrous pyrolysis, a procedure for simultaneously dissolving heavy oil components and cracking them at subcritical temperature and pressure. The programme has identified new challenges in their existing work, which bodes well for its future viability. While the retirement of the programme leader, Prof. Brouwers, will necessarily be somewhat disruptive, this does not give rise for concern at this juncture. However, it goes without saying that his replacement must

be chosen with care so that new strategies can arise without jeopardising the strengths already in place, given the number and range of the current tenured staff.

The difficulty in filling PhD and post-doc positions – as well as in finding female students – is not something that is unique to this programme, unfortunately; the step that the programme is taking to counter the problem – seeking candidates from abroad - is welcome, and the Committee wishes them success with this endeavour. In the early stages of this plan, the programme may need to be cautious while 'calibrating' the potential of those students against the challenges of studying for a PhD in the programme.

The funding source of the programme has fluctuated significantly over the past 6 years, with public grants ranging from 31% to 59% of the annual funding, and contract research ranging from 66% to 23%. Additionally, the annual funding has ranged from €388 million to €1005 million. Such observations no doubt reflect the 'statistics of small numbers' of research grants and contracts, but the general trend that "…the number of projects funded directly by industry or by STW increased significantly, and this has resulted in a proportional growth of our industrial network…" is a structural one. However, the equipment in the laboratories is an important capital asset that depreciates each year. The programme would do well to set aside some thought, and perhaps funding, for investing in this asset in the future.

Conclusion

The Process Technology programme has internationally competitive expertise in several fields of process technology; it has been productive, it has had some impact within the community, and has been active in finding some viable, long-term research topics that serve the needs of society. The programme has chosen these topics carefully and has tenured staff who are able to pursue good research in these topics. It is currently a viable programme and should remain so for the next review period. The rate-determining step in the long term is always the recruitment of able PhD students, and the programme has already identified this as a threat. Searching for students abroad and outside the EU is a natural 'defence' strategy but one whose execution demands much greater care and vigilance than is the case in recruiting home-grown students. The programme should address the perception, and perhaps the reality, that the core engineering science subjects at undergraduate level are 'difficult' in innovative ways and pursue, in parallel, recruitment from the EU network for PhD students. The latter fits in with the programme's declared strategy – and the imposed necessity – of increasing European funding. In the short term, the retirement of the current programme leader and the finding of his replacement will inevitably present threats but also opportunities. Properly addressed, and with a little luck, the latter should outweigh the former.

2.B.7 Programme: Multiscale Engineering Fluid Dynamics

Programme leaders:	Prof. E.H. van Brummelen	
Research staff 2012:	4.3 fte	
Assessments:	Quality:	5
	Productivity:	4
	Relevance:	4
	Viability:	4

Within the wide scope of computational science and engineering, the research in the Multiscale Engineering Fluid Dynamics programme focuses in particular on free boundaries and evolving discontinuities and interfaces, multi-field interactions such as fluid-structure interaction, and transitional molecular/continuum flows. Complementary to the above application areas, the research in this programme addresses fundamental aspects of numerical models and techniques at a generic level, for example, error estimation, optimal adaptive refinement and isogeometric analysis.

The Multiscale Engineering Fluid Dynamics programme was established in November 2009. The first PhD student in the programme graduated in December 2013. This is after the current review period.

Quality

The programme leader came from an internationally highly visible programme at TU Delft and now personally has a good reputation. He maintains close cooperation with some programmes in the USA, especially in Austin. The strong background of the tenured staff members is evident in the citation scores of the publications realised so far. The Mean Normalised Citation Score (MNCS) is 2.82, which is extremely high. However, it is noted that some of the publications derive from excellent cooperation with other programmes and cannot be seen as purely in-house quality marks. An analysis of the citation score also reveals that a majority of citations comes from a limited number of people and hence indicates a network bonus. About 63% of the journal publications are in top-25% journals. With these figures it is clear that the overall quality of the research output of the programme is excellent. This quality concerns the originality of the research topics and the developed computational methods. The international visibility of the tenured staff members is obvious. However, at the current stage, it is impossible to verify if the tenured staff members have an international reputation due to the young status of the programme. The assistant professors active during the assessment period both obtained a VENI grant, which is a proof of their high research quality. Further, the Committee appreciates the well-defined training programme for PhD students, with its rather strict assessment.

Productivity

The number of refereed journal publications in the years 2010-2012 was 16. The number of conference publications was somewhat higher (18), and there were contributions to books as well. The productivity in terms of number of refereed journal articles per year and per tenured-track person (16 publications in 3 years for the equivalent of 1 person) is above 5. This is a very high number, showing that the productivity is excellent. The Committee took

into account that the research output is still a prolongation of the research that group members did with the Austin group and therefore marked the productivity as 4. In the review period, no PhD theses were completed, but this cannot be interpreted as a lack of productivity since the research programme only started at the end of 2009.

Relevance

The chosen research topics are: 1) free boundaries, interfaces and discontinuities; 2) error estimation and adaptive refinement; 3) isogeometric analysis and 4) transitional molecular/continuum flows. These topics are all relevant for the broad field of computational fluid dynamics. The research topics are rather upstream compared to more applied ones, and hence their societal relevance is more indirect through a service to downstream applications.

Viability

The research programme is currently in a development phase. The number of PhD students is steadily increasing. A recruitment procedure is continuing for a new assistant professor and a part-time professor from industry. The amount of funding obtained by the programme in the past years has allowed the growth in the number of PhD students. Research funding has been on the national level up to now. Thus, the programme will have to make an effort to acquire funding on the international level and also funding from industry based on high-level sustainable research topics, and not only collaborations. This potential is certainly present, though its use has been limited so far. For example, the programme has not yet formulated a strict plan for the future regarding acquiring funds on the international level. The Committee understands that the research programme is currently focussing on expansion and on acquiring as much funding as possible for any of the topics covered by the programme. It is convinced that after a growth and consolidation phase, the research programme will have to determine on which topics to continue its work. Thus, it recommends striving to focus.

The Committee remarks that the Multiscale Engineering Fluid Dynamics programme has a research project on crack propagation with applications to hydraulic fracturing. It sees an activity on the same topic in the Energy Technology programme. However, neither of the programmes has mentioned a possible cooperation on this topic.

Conclusion

The Committee recognises the high quality of the Multiscale Engineering Fluid Dynamics programme and understands that its primary concern for the next few years is expansion. It recommends that the research programme already start thinking during this expansion period about choosing a limited number of research topics on which to focus. Further, it recommends investigating a possible cooperation between the Multiscale Engineering Fluid Dynamics programme and the Energy Technology programme on the topic of hydraulic fracturing.

2.B.8. Programme: Polymer Technology

Programme leaders:	Prof. H.E.H. Meijer	
Research staff 2012:	22.0 fte	
Assessments:	Quality:	5
	Productivity:	4.5
	Relevance:	4.5
	Viability:	5

The programme covers the science and technology in the field of polymer processing and design, utilizing experimental and computational tools in the analyses of the full thermo-mechanical history of materials during their formation, processing and final design, to quantitatively predict the properties of processed objects. Until 31 December 2011 the programme covered both fluid mechanics and solid mechanics. Since then, it has been split into two smaller programmes, the first focusing on Fluid Mechanics and Structure Development during Flow, the second on Solid Mechanics and Structure-Property Relations. Patrick Anderson was appointed on January 1, 2012, as a full professor in the fluid-focused area. To emphasize the seriousness of this launch, half of the programme (20 people) was directly placed under his supervision, including their funding. The department is at present designing the procedure to find a successor for the solid-focused programme.

Quality

The TU/e has a longstanding tradition in the discipline of Polymer Technology, and the programme and many of its staff members are internationally renowned. The programme publishes in leading international journals and conducts cutting-edge fundamental research. The researchers with high H-index have clear international recognition. The strong ties with top international programmes are further evidence of the high-quality research conducted in this programme. The CWTS study shows that the Polymer Technology programme was one of the most productive programmes relative to its size and had 10% of papers in the top 10 journals and 28% in the top 25 journals, and a Mean Normalised Citation Score (MNCS) of 1.07.

Productivity

The quality of papers produced by this programme is at the top international level. The number of citations of these papers is quite high, as can be deduced from the h-index of the leader of this programme, which is higher than that of comparable leaders at other universities (and increasing every year).

The number of published papers is generally very high but shows a sharp drop in 2012 from 41 to 26. Reason for this drop is the split of the Polymer Technology programme into two programmes, which causes a start-up effect. Patent numbers are low and are obviously not a focus of the programme. The number of published PhD theses per fte is below the average of the Department. NWO research grants like VENI, VIDI and VICI as well as ERC research grants have not been awarded to staff here.

Relevance

The relevance of the research is confirmed by the large number of projects with industrial participation. Various spinoffs, e.g. IME Technologies, are a further sign of the societal relevance of the research work of this programme. The lack of interest by Master students on the pre-research level has to be improved in order to maintain links to the next generation. Intensified interaction with small and medium-sized enterprises would increase the social impact of the programme even further.

Viability

The programme has made a strategic decision to split itself into two smaller programmes with a focus on fluid and solid mechanics, respectively. The Committee considers this to be strategically well chosen, since this will increase the dynamics of this research field and will enable specialised experts to be appointed in each field.

The recruitment of two new staff members through funding from the university's high-potential programme has strengthened the future of the programme considerably.

Conclusion

The Polymer Technology programme is an excellent research team with outstanding research potential. The appointment of the new chair should be concluded as quickly as possible. Both the report and the interviews reflect the impression that the staff is proud of their glorious research history. However, this should not hinder them from critically evaluating their current research status.

2.B.9 Programme: Structure and Rheology of Complex Fluids

Programme leaders:	Prof. P.D. Anderson	
Research staff 2012:	11.7 fte	
Assessments:	Quality:	5
	Productivity:	4.5
	Relevance:	4.5
	Viability:	5

The programme works in the area of complex fluids and seeks to develop and apply novel computational and experimental methods to study the flow and dynamics of complex fluids in areas where morphology and rheology are inherently coupled. It covers the entire spectrum from fundamental understanding via method development to the potential application to industrially relevant problems. Their scientific activities range over application areas from polymer processing to cellular biophysics. Until 31 December 2011 the programme was linked with the Polymer Technology programme. Since the two programmes were together for most of the review period, the assessment will be a kind of joint assessment. However, the Committee has also tried to make specific remarks about this start-up.

Quality

The Structure and Rheology of Complex Fluids programme publishes in leading international journals and conducts cutting-edge fundamental research. The top-quality researchers have a clear international recognition. The strong ties with leading international programmes are further evidence of the high-quality research conducted in this programme. The CWTS citation analysis reveals that papers of this programme are well above the world average, with a MNCS of 1.79.

Productivity

The number of published papers is excellent (in 2012 the programme published 35 refereed papers). The number of published PhD theses per fte has fluctuated over the years and the particular performance in 2012, while low, is not representative of the programme as a whole (see under 'Viability'). Also, NWO research grants like VENI, VIDI and VICI as well as ERC research grants have not been awarded to staff here. This might have an effect on future publication figures.

Relevance

The programme works on a number of very timely topics. The large number of projects with industrial participation also demonstrates the relevance of the research. Various spinoffs are a sign of the social relevance of the research. The only concern is the obviously very limited visibility among students and the lack of success in attracting more of them to this fascinating field.

Viability

The programme has made a strategic decision to split itself into two smaller programmes with a focus on fluid and solid mechanics, respectively. While this could be considered a risky step, it is already obvious that both new programmes are very viable. Given the selected research areas, the existing research facilities and the quality of the staff, the Committee is not worried about the future of this young programme. Indeed, the productivity in terms of PhD theses has been strong in the period 2013 & 2014 and above the average of the institution, which is to be welcomed. Obviously, the programme is very dependent on the Dutch Polymer Institute (DPI), which could be considered a great risk. However, it seems that the programme is aware of this, and the DPI will be replaced by the new polymer centre.

Conclusion

The Structure and Rheology of Complex Fluids programme has an excellent research team with outstanding research potential. Although quite young, it is already stable and productive on a high international level. The Committee's main concern was its evident lack of attractiveness for students. However, it became clear in the report and in the interviews that the programme leader is aware of the importance of attracting students and has already planned and started taking appropriate measures.

2.B.10 Programme: Mechanics of Materials

Programme leaders:	Prof. M.G.D. Geers	
Research staff 2012:	18.1 fte	
Assessments:	Quality:	5
	Productivity:	5
	Relevance:	5
	Viability:	5

The mission of the Mechanics of Materials programme is to understand, predict and optimise the mechanical response of high-tech materials and products as a function of their underlying microstructure, processing and evolution, through focused and co-ordinated experimental, theoretical and computational efforts. The goal of this work is to make a key contribution to the effort of industry to develop novel products with revolutionary functionality. At present, the programme consists of 8 scientific faculty members (2.5 fte research capacity).

Quality

The programme leader strives for scientific excellence, which is reflected in his scientific goals. These goals are quite ambitious but sufficiently focused, namely the study of the mechanical behaviour of materials (mostly engineering) at all length scales, both experimentally and by modelling, from the conviction that this is the only way to fundamentally understand the relationship between material performance and material structure. The strategy has earned him and his co-workers an excellent publications output with a lot of citations and h-factors with a rate of increase of about 1 per year after promotion, which is rarely outperformed in the field of materials. The staff members of this programme have received an Advanced Grant from ERC, a Rubicon Grant, two VENI grants and a VIDI grant from NWO. The programme also has an international scientific network of a high level and maintains excellent relationships (and co-operation) with several industries (those who actively develop advanced materials are highly interested in the multi-scale approach of this programme). In addition, they succeed in getting important research grants from various agencies.

Productivity

The strategy-by-quality seems to work very well when it comes to having a large output of top-level papers (varying from 35 to 54 academic publications per year). The funding strategy is very well balanced, meaning that a good mix has been obtained between the various sources of funding (ranging from ERC grants to bilateral research contracts with industry).

The research facilities are of a rather specialised nature, since they are intended to study material behaviour at different length scales, to experimentally validate multi-scale models. As such, this laboratory has almost no rivals anywhere in the world. It is also accessible to all industries that collaborate with this programme through co-operative research programmes. Such collaborations are needed, since the laboratory possesses hardly any manufacturing know-how and facilities.

One small remark with regard to productivity is that the productivity strategy is not precisely stated.

Relevance

While this programme essentially wants to put its mark on the international progress of the field and rivals the best programmes in the rest of the world scientifically, its societal relevance is also high. A good example is the effort by the important steel companies to further develop advanced two-phase steels ("dual phase", TRIP, TWIP). Fundamental understanding of the behaviour of these materials is only possible through a multi-scale approach, and this programme contributes to it, also in collaboration with some of these companies. In the Netherlands such work is currently being organised by M2i, a large Dutch institute that finances and organizes collaborative materials research between industry and universities. Prof. Marc Geers is one of the "cluster leaders " of M2i. M2i is also of great help with valorisation of the results of research projects in industry.

The general public would not find the subject of this research very accessible. This might be improved with the help of professional experts in public relations, provided money could be made available to hire them. The programme was awarded a relatively large number of patents. A small remark is that there is not much collaboration with non-Dutch companies.

Viability

The financial situation of the programme will enable further investments in infrastructure during the next five years, especially in the "Multi-Scale Lab", which is an investment in future competitiveness due to its uniqueness. The Committee noted that the SWOT analysis presented by the programme seems very complete and realistic, and offers no reason for alarm. However, an effort must be made to find sufficient numbers of well-qualified candidates for PhD positions, because the scientific standard of this programme is high.

Conclusion

The Mechanics of Materials programme can be called excellent: the two full professors are of the highest academic level, the associate professors also contribute clearly to the generation of high-level research and to the development of the very exclusive, experimental, multi-scale laboratory. It remains a challenge to find sufficient numbers of highly qualified PhD students for all research projects. The meta-strategy of the programme is to go for high scientific quality; this is being carried out successfully. However, it takes a lot of energy and aims at technological progress in the mid-term or long term rather than the short term. However, from a societal point of view, this is not necessarily a drawback.

2.B.11 Programme: Microsystems

Programme leaders: Prof. J.M.J. den Toonder
Research staff 2013: 5.3 fte

Trends in microsystems science and technology include the ongoing miniaturisation, increased function integration, adaptivity to environmental conditions, interaction and merging with biological materials and low-cost manufacturing approaches. The mission of the Microsystems programme is to carry out excellent scientific and technology-driven research that contributes to these developments. The concrete objectives are the investigation and development of novel microsystems design approaches and rapid, flexible, out-of-cleanroom, micro-manufacturing technologies. They are applied to achieve active mechanical control in micro-fluidics, to create and study cells and organs on chips, to investigate integrated microsystems that combine optics, fluidics and mechanics, and to develop advanced microsystems applications with industrial partners.

Quality

The recent decision by TU/e to launch a new programme in Microsystems is an excellent and timely idea. The Committee especially appreciates the decision to focus effort on materials and applications that can be addressed with relatively inexpensive fabrication facilities (instead of requiring a complete cleanroom with high-resolution lithography, deposition and etch tools on 200mm wafers). This approach should lead to success and important results with a modest investment in a relatively short time. It is absolutely imperative that the institution follow through with the planned facilities as soon as possible, as this programme cannot succeed without them.

The initial group of faculty hired for this programme is highly qualified, experienced and balanced. The addition of new junior faculty with complementary interests will be important. Also, collaboration within this programme to combine their strength and experience to achieve early success will be important.

It is too early to assess the reputation, the training and the quality of the research. We look forward to these results becoming clear in the next interval.

Productivity

It is far too early to provide any assessment of performance in this category. All that can be said is that this team has the potential to be highly productive.

Relevance

In this category, the decisions already made are clearly aligned with a research programme that will be relevant to society. The interface between traditional engineering science and biology, and the opportunities associated with the unique properties of materials at the microscale, are clearly aligned with societal impact.

Viability

The team was launched with a good strategy, which recognizes the realistic limitations that are part of their initial situation, and the opportunities for significant impact looking ahead. The SWOT analysis is really premature, but indicates an appreciation of the opportunities and challenges. Robustness and stability will depend on a serious institutional commitment, beginning with the completion of the planned microfabrication facility, and with the matching funds and new faculty positions necessary to launch new projects and new careers.

Conclusion

The team is well qualified, experienced and balanced. The strategy, which recognizes the realistic limitations that are part of their initial situation, is good, and there are opportunities for a significant impact looking ahead. For the success of the programme, it is extremely important that the institution follows through with the planned facilities as soon as possible, as this programme cannot succeed without them.

Appendices

Appendix 1: Curricula vitae of the committee members

Frank Allgöwer is director of the Institute for Systems Theory and Automatic Control and full professor in Mechanical Engineering at the University of Stuttgart in Germany. His main interests in research and teaching are in the area of systems and control with an emphasis on the development of new methods for the analysis and control of nonlinear systems, networks of systems and systems biology. He has received several recognitions for his work including an appointment as IFAC Fellow and IEEE CSS Distinguished Lecturer, the IFAC Outstanding Service Award, the state teaching award of the state of Baden-Württemberg, and the Leibniz Prize of the Deutsche Forschungsgemeinschaft. At present, he is serving as IEEE CSS Vice-President for Technical Activities and is President-elect of the International Federation of Automatic Control. He is Editor for the journal *Automatica* and for the Springer Lecture Notes in Control and Information Science book series and serves as associate editor or on the editorial board of several further journals. He has been an organizer or co-organizer of more than a dozen international conferences and has published over 200 scientific articles. Since 2012 he has served a Vice-President of the German Research Foundation (DFG).

Erik Dick was born on December 10, 1950, in Torhout, Belgium. He obtained a MSc in Mechanical Engineering from Ghent University (Belgium) in 1973 and a PhD in Computational Fluid Dynamics from the same university in 1980. From 1973 to 1991, he worked at Ghent University as researcher, senior researcher and research leader in the turbomachinery division of the Department of Mechanical Engineering. He became associate professor of thermal turbomachines and propulsion at the University of Liège (Belgium) in July 1991. He returned to Ghent University in September 1992 as associate professor and became full professor in 1995, where he teaches turbomachines and computational fluid dynamics. His area of research is computational methods and turbulence and transition models for flow problems in mechanical engineering. He is author or co-author of about 120 papers in international scientific journals and about 220 papers at international scientific conferences. He is the recipient of the 1990 Iwan Akerman award for fluid machinery of the Belgian National Science Foundation and of the 2002 Belgian Francqui Chair with a lecture series on simulation and modelling of complex flows at the University of Liège.

Paul Van Houtte (Antwerp, 1948) graduated in 1970 with a MSc in Mechanical Engineering from the Katholieke Universiteit Leuven (KULeuven), where he also obtained a PhD in Metallurgy (1975). From 1972 on, he worked as a scientist at the Department of Metallurgy and Materials Engineering of the KULeuven. He became full professor in 1995. From 1996 until 2004 he was chairman of the department. Since 2008, he has been the Chairman of the Commission on Scientific Integrity of the KULeuven. He became Emeritus Professor on 1 January 2013. He is well known for his work in the fields of crystallographic textures of materials, residual stresses and plasticity theory. He is author or co-author of about 200 papers in scientific peer-reviewed journals and of about the same number of papers in the proceedings of international scientific conferences. In 2004 he was elected a Fellow of the Institute of Physics in London. In 2013, the Société Française de Métaux et Matériaux awarded him de Sainte Claire-Deville Medal. In 2014, he received the "Khan International Medal" at "Plasticity 2014" in Freeport, Bahamas. He also holds some positions outside the KULeuven: in 2008, he was elected Chairman of the International Committee of ICOTOM (the main series of international conferences on Textures of Materials), and recently he was elected the Governor of the Class of Natural Sciences of the Royal Flemish Academy of Sciences and Arts of Belgium (2014).

Bernhard A. Schrefler (chair) holds a ME degree in Structural Engineering from the University of Padua (summa cum laude), a PhD and DSc from Swansea University, Wales. He is Secretary General of the International Center for Mechanical Sciences (CISM) in Udine, former Professor of Structural Mechanics at the University of Padua (until 2013), and Senior Affiliate Member of the Department of Nanomedicine of the Houston Methodist Research Institute, TX. For his research work, he has been awarded the Maurice A. Biot Medal from ASCE, the Euler Medal from ECOMAS, the Olgierd C. Zienkiewicz Medal from PACM, the Computational Mechanics Award from IACM, the IACM Award and the Palmes Académiques in France. He has received honorary doctorates from the St. Petersburg State Technical University, the University of Technology of Lodz, the Leibniz University of Hannover, the Russian Academy of Sciences and the Ecole Normale Supérieure at Cachan, an honorary fellowship from the University of Wales Swansea, and an honorary professorship from the Dalian University of Technology. Dr. Schrefler is a member of the National (Italian) Academy of Sciences ("dei XL"), of the Accademia Galileiana di Scienze, Lettere ed Arti, of the Istituto Veneto di Scienze, Lettere ed Arti.

Alex Taylor graduated from the Imperial College of Science & Technology with a first-class honours in Mechanical Engineering in 1975 and received his PhD degree from the same institution in 1981. Following brief periods as a temporary lecturer and a post-doctoral research fellow, including a spell at NASA Lewis (now Glenn), he won a Royal Society Research Fellowship in 1985. In 1990 he was appointed lecturer, and then promoted to professor in 1999. He was an Editor of the Springer Journal *Experiments in Fluids*. In 2009 he was elected to the Fellowship of the Royal Academy of Engineering. His interests include experimental research, using optical instrumentation, into turbulent flows, two-phase flows and flows with combustion as well as their application to spray dryers, internal combustion engines and gas turbines.

A. Erman Tekkaya is professor at the Technische Universität Dortmund, Germany, and has led the Institute of Forming Technology and Lightweight Construction (IUL) since 2007. He started as assistant professor in 1986 at the Mechanical Engineering Department of the Middle East Technical University in Turkey and was promoted in 1993 to a full professor. He was the founding chairman of the Manufacturing Engineering Department at the Atilim University (Turkey) and founding director of the Metal Forming Center of Excellence. Since 2013 he has been the vice-dean of the Faculty of Mechanical Engineering at the Technische Universität Dortmund. He has been editor-in-chief of the *Journal of Materials Processing Technology* (Elsevier) since 2007. He is a fellow of the International Academy for Production Engineering (CIRP) and a member of the German National Academy of Science and Engineering (acatech), the Japan Society for Technology of Plasticity (JSTP), the International Impulse Forming Group (I²FG) and the International Cold Forging Group (ICFG). He is a member of the review board for manufacturing technology of Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) and the Allianz Industrie Forschung (AiF). His research interests are metal forming technology, modeling of manufacturing processes and material characterization. Engineering education is also a prime interest of his.

Wolfgang A. Wall has been a full professor and founding director of the Institute for Computational Mechanics at the Technische Universität München in Germany since 2003. He received his diploma in Civil Engineering from the University of Innsbruck (Austria) and his PhD from the University of Stuttgart (Germany) in 1999. He was a founding director of the Munich School of Engineering and is co-founder of the company AdCo Engineering^{GW}. Wolfgang A. Wall serves on several editorial boards of leading international journals and is

currently president of the German Association of Computational Mechanics, Chairman of the ECCOMAS CFD committee, and member of the executive council of IACM. He has received several awards, including the IACM Fellow award in 2008, the Computational Mechanics award in 2012, the Heinz Maier-Leibnitz Medal in 2013 and several Golden Teaching awards. His research interests can be described as "application-motivated fundamental research" in a broad range of areas in computational mechanics, including both computational solid and fluid mechanics. His current focus is on multifield and multiscale problems in all fields of engineering and the applied sciences as well as on computational biomedical engineering. In all these areas his group covers the full cycle from advanced modelling to the development of novel methods to advanced software development and to application-oriented simulations on high-performance computers, while including optimization, inverse analysis, uncertainty quantification aspects as well as his own experimental work.

Appendix 2: Explanation of the SEP scores

Excellent (5)	Research is world leading. Researchers are working at the forefront of their field internationally and their research has an important and substantial impact in the field.
Very Good (4)	Research is nationally leading. Research is internationally competitive and makes a significant contribution to the field.
Good (3)	Research is internationally visible. Work is competitive at the national level and makes a valuable contribution in the international field.
Satisfactory (2)	Research is nationally visible. Work adds to our understanding and is solid, but not exciting.
Unsatisfactory (1)	Work is neither solid nor exciting, flawed in the scientific and/or technical approach, repetitions of other work, etc.

Quality is to be seen as a measure of excellence and excitement. It refers to the eminence of a group's research activities, its abilities to perform at the highest level and its achievements in the international scientific community. It rests on the proficiency and rigour of research concepts and conduct; it shows in the success of the group at the forefront of scientific development.

Productivity refers to the total output of the group; that is, the variegated ways in which results of research and knowledge development are publicised. The output needs to be reviewed in relation to the input in terms of human resources.

Societal relevance covers the social, economic and cultural relevance of the research. Aspects are:

- societal quality of the work. Efforts to interact in a productive way with stakeholders in society who are interested in input from scientific research, and contributions to important issues and debates in society.
- societal impact of the work. Research affects specific stakeholders or procedures in society.
- valorisation of the work. Activities aimed at making research results available and suitable for application in products, processes and services. This includes interaction with public and private organisations, as well as commercial or non-profit use of research results and expertise.

Vitality and feasibility. This dual criterion regards the institute's ability to react adequately to important changes in the environment. It refers to both internal (personnel, research themes) and external (developments in the field, in society) dynamics of the group. On the one hand, this criterion measures the flexibility of a group, which appears in its ability to close research lines that have no future and to initiate new venture projects. On the other hand, it measures the capacity of the management to run projects in a professional way. Policy decisions and project management are assessed, including cost-benefit analysis.

Appendix 3: Programme of the site visit

Tuesday May 13th Eindhoven
17:30 hr: meeting of the committee in preparation of the interviews in the Hampshire hotel - Crown Eindhoven

Wednesday May 14th Eindhoven, TU/e-Gemini-Zuid 1.03

Time	*Activity*	*Present*
08.15 – 08.25	Welcome address by the Rector Magnificus	Dept. Board
08.25 – 08.55	Meeting with the Dean + Department level	Dept. Board
09.00 – 09.25	Programme 1: *Control Systems Technology*	Steinbuch + Heemels
09.25 – 09.50	Programme 2: *Dynamics and Control*	Nijmeijer + V/d Wouw
09.50 – 10:15	Programme 3: *Manufacturing Networks*	Adan + Fokkink
10:15 – 10:45	Break	
10.45 – 11.10	Programme 4: *Combustion Technology*	De Goey + Johansson
11.10 – 11.35	Programme 5: *Energy Technology*	Smeulders + Van Steenhoven
11.35 – 12.00	Programme 6: *Process Technology*	Kuerten + Brouwers
12.00 – 13.00	Lunch with PhD students and Post-Docs	
13.00 – 13.25	Programme 7: *Multiscale Engineering Fluid Dynamics*	Van Brummelen + Verhoosel
13.25 – 13.50	Programme 8: *Polymer Technology*	Peters + Govaert
13.50 – 14.15	Programme 9: *Structure and Rheology of Complex Fluids*	Anderson + Wyss
14.15 – 14.35	Break	
14.35 – 15.00	Programme 10: *Mechanics of Materials*	Geers + Peerlings
15.00 – 15.25	Programme 11: *Microsystems*	Den Toonder + Luttge
15.25 – 16.45	Lab visit	Committee + staff
16.45 – 17.00	Break	
17.00 – 18.00	Committee meeting – discussion TU/e programmes	Committee only
18.00 – 20.00	**Dinner	
20.00 – …	Committee meeting – reporting on TU/e programmes	Hotel, committee only

Thursday May 15th Eindhoven (until 11 hr), TU/e-Gemini-Zuid 1.03

Time	*Activity*	*Present*
08.30 – 10.30	Conclusions and final reporting TU/e programmes	Committee only
10.30 – 11.00	Meeting with the Dean + Departmental Board	Dept. Board
11.00	Departure to Enschede	