Research review
Mechanical Engineering
Delft University of Technology

2007 - 2012

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Project number: Q 0470

Report on the research assessment of Mechanical Engineering at Delft University of Technology

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Preface by the chairman

The External Review Committee was given the task to evaluate the research of the Faculty of Mechanical, Maritime and Materials Engineering (3mE) of Delft University of Technology. The review covers the research in the period 2007-2012.

As Chair of the Review Committee, I wish to thank the Committee members for their valuable contributions, for the time they were willing to spend, and for the discussions in the Committee meetings which were fruitful and led to consensus.

The Committee appreciated the thorough self-evaluation report that was provided by the Faculty, the intense but pleasant visit to the Faculty and its Departments, and the openness of the interviews and discussions with the Rector Magnificus, the Dean, department heads, group leaders, staff members, and PhD students.

The assessment is presented in numbers, scores, and text. We strongly believe that the scores are only one element in the assessment, and they should never be used as the sole basis for policy decisions. The textual material of the report, including the written evaluations, the objectives, the context and the stage of development of the programmes and departments, must be taken into account.

The averaging required on the department level removes the differences observed by the Committee between individual programmes. All departments have some top-level and some weaker research projects. Furthermore, the scores are only to be interpreted with the field of research in mind.

The Committee hopes and trusts that the feedback that this report is intended to provide will be used wisely in the quality assurance procedures of Delft University. Several remarks are intended as suggestions for improvement rather than as criticisms.

The Committee wishes to thank Annemarie Venemans, the Committee's Secretary, for her important assistance, guidance of the process, advice in the preparation of the visit, and the completion of the final report.

Prof. Dr-Ing. Norbert Peters

Chairman of the Review Committee

1. The Review Committee and the review procedures

Scope of the assessment

The External Review Committee was asked to perform an assessment of the research in Mechanical Engineering at Delft University of Technology. This assessment covers the research in the period 2007-2012. In accordance with the Standard Evaluation Protocol 2015-2020 for Research Assessment in the Netherlands (SEP), the Committee's tasks were to assess the quality of the Faculty and the Departments on the basis of the information provided by the Faculty 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. Dr.-Ing. Norbert Peters (chair), RWTH Aachen, Germany;
- Prof. Dr. ir. Rene Boel, Ghent University, Belgium;
- Prof. Dr. Neville Hogan, Massachusetts Institute of Technology, US;
- Prof. Dr. Torgeir Moan, Norwegian University of Science and Technology, Norway;
- Prof. Dr. Bradley Nelson, ETH Zürich, Switzerland;
- Prof. Dr. Rudolf Von Rohr, ETH Zürich, Switzerland;
- Prof. Dr. Frans Spaepen, Harvard University, US.

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 the 3mE Faculty and its departments in an unbiased and independent way. Any existing personal or professional relationships between Committee members and the Faculty under review were reported and discussed in the Committee 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 has received detailed documentation consisting of the following:

- Self-evaluation report of the units under review, including all the information required by the Standard Evaluation Protocol (SEP), with appendices;
- Copies of key publications of each department.

Procedures followed by the Committee

The Committee proceeded according to the Standard Evaluation Protocol 2015-2020 (SEP). The self-evaluation report was written according to the previous Standard Evaluation Protocol (2009-2015). Prior to the first Committee meeting, all Committee members independently formulated a preliminary assessment of the Departments. 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 departments. The interviews took place in Delft on 14–16 April 2014 (see the schedule in Appendix 3).

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 Mechanical Engineering 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 2015-2020 (SEP). The meaning of the scores is described in Appendix 2.

2. General remarks

Mechanical Engineering can perhaps be qualified as the broadest field of engineering emerging from the beginning of the technical revolution in the early 19th century. It has continued to evolve since then, splitting off specialist fields like electrical engineering, and integrating ideas from the natural sciences to cover modern knowledge ranging from fundamental science to fully functional applications.

The classical areas of research in university-level engineering schools are concerned with design and manufacturing and, since the early days, with the control of mechanical systems like the steam engine. Today, associated analytical, numerical and experimental methods in solid and fluid mechanics, in thermodynamics and in control theory play an equally important role. Related key areas are combustion and other energy conversion processes, the sustainable production of electrical energy and the delivery of health care.

Novel applications of technology, systems integration and the development of new products have always been part of programmes at the graduate research level. Mechanical Engineering Departments in top universities proved themselves to be particularly well prepared to embrace fundamental new results and provide the engineering know-how for further developments towards innovative technological applications in associated industries.

Innovation in terms of new applications that result from research findings is very difficult to steer or predict. It requires broad and fertile feeding grounds, long-term perspectives and opportunities for spin-offs. The road from discovery to market can be long and arduous, and contains many challenges in areas including risk investment, product development, marketing and staffing.

3. Research review Faculty of Mechanical, Maritime and Materials Engineering (3mE)

3.1 The institute

Global challenges such as energy, security, healthcare, environment, food supplies, housing, water, high-tech systems and transport need solutions for a more sustainable way of living in the coming decades. The vision of the faculty is to find solutions, which have enhanced material properties with increased functional density and integration, as well as multi-scale and multi-disciplinary engineering approaches across greater distances and timeframes. Research contributions rely on links between various disciplines, and demand knowledge of the full range of both fundamental and applied science.

The Faculty of Mechanical, Maritime and Materials Engineering (3mE) educates MSc and PhD students to become committed engineers and conducts breakthrough scientific research in the fields of mechanical engineering, maritime engineering, materials science, and clinical technology. The faculty focuses on four strategic research themes: health, high-tech systems & materials, process technology and transport. All departments within the faculty participate in these themes, which include research areas such as micro/nanotechnology, (bio)mechanics, fluid dynamics, energy and off-shore.

The 3mE Faculty consists of six departments, each with three or four research programmes. Each department is chaired by a department head, who is the integral manager of that department. At the head of the Faculty is the Dean, who is the integral manager of the Faculty. Together with the management team of the Faculty (six department heads, finance and HR managers, and the secretary to the Faculty), he makes strategic deliberations and decisions for the faculty.

Assessment/remarks
Overall, the structure of the Faculty is well-balanced, and the groups are similar in size. The laboratory facilities are shared, without an administrative body but on an ad-hoc basis. This is a great strength: it promotes collaboration, the waiting times are short, and the administration costs are minimal. This culture of collaboration is also reflected in the research activities.

The research focus of the Faculty emerges from the collective wisdom of its members. The self-evaluation report is not sufficiently detailed to confirm that all staff members, especially the intermediate level ones between the full professors and the younger assistant professors, contribute to this high quality of research output. Improving the external visibility of this group of staff members could improve their motivation, and could help the Faculty in attracting bright young researchers to tenure track positions.

In accordance with the traditions in Mechanical Engineering, the Faculty members and their staff plus the PhD students and post-docs have a high teaching load. They have so far taken up this load without complaining. As the Committee notes in its assessment of the vision for the future below, the difficulty in attracting new staff may well aggravate this situation to a point where it is no longer bearable.

3.2 Quality and academic reputation

Significant results of the research are described in the department evaluations in the self-evaluation report. At the Faculty level, the total number of personal grants is given, which include a number of VENI and VIDI grants, one VICI grant, some ERC grants and other personal grants. Furthermore, some prestigious prizes and awards are mentioned.

According to the Faculty, a bibliometric analysis shows that there were a total of 1,844 publications, which were cited 15,592 times excluding self-citations. The Mean Normalized Citation Score (MNCS) is 1.30 and impact value is 1.22. Around 14% of the publications are among the top 10% of most highly cited papers. Of all papers, 65% were joint publications.

Assessment/remarks
The quality of the research programmes is high; some programmes are world class in their niche domain. The researchers showed great motivation and enthusiasm during the site visit. The publication record in refereed journals is impressive for an engineering faculty, where conference publications often play an important role, because the rapid dissemination of technical innovations is of primary relevance. Some issues per group may require action, as indicated in the programme assessments.

On the whole, the Committee believes that all departments have developed their own area of expertise on which they can build in the future. They should target this research to obtain a competitive advantage.

The international collaboration is healthy, and the national collaboration with the other technical universities in the Netherlands is distinctive.

3.3 Resources

The total funding of the Faculty has increased during the period of review, with the percentages of first-, second- and third-stream funding remaining fairly stable. The Faculty expects that first-stream funding will decrease in the future, providing the challenge and necessity to acquire alternative funding. Its focus is shifting from national to European funding.

Budget allocations at TU Delft have been restructured recently to link the funding to strategic decisions rather than to output. The 3mE Faculty has increased its research grants as well as its contract research in the review period.

High-quality facilities are considered indispensible in a good research environment, both for conducting research and to remain an attractive partner in research. Each department has its own equipment, some of which is shared with other departments, sometimes also with other faculties at Delft University and faculties at the other technical universities in the Netherlands. The resources in terms of experimental equipment and analytical tools are excellent.

Assessment/remarks
Funding, especially the external funding, has grown considerably. The Faculty has shown great flexibility in adapting to changes in the funding policy. In most cases a decline in direct funding has been compensated by an increase in external funding. The external funding policy appears to be a group-based one rather than a Faculty policy. The Committee notes that while the importance of renewal in research is still fully recognised by the Faculty

members, the reduction of government funding now threatens the knowledge base and the pool of next generation researchers. In return, there should be support at University level for the competition for European funding.

Sharing equipment and cooperating with other technical universities in the Netherlands is viewed by the Committee very positively. This should be encouraged further.

3.4 Societal relevance

The 3mE Faculty encompasses a wide variety of research fields that are societally relevant. Research projects, patents, invited lectures and start-up companies are mentioned as examples of its societally relevant output.

Every two years a stakeholder's event is organised. Industrial leaders, delegates from research institutes and public organisations are invited to discuss a number of propositions. These concern not only research, but also education.

According to the self-evaluation report, the research at 3mE affects different stakeholders in a variety of ways. The industry benefits from the research results (sometimes patented). Many part-time professors are partly or fully supported by industry or have positions at other universities or research organizations.

The self-evaluation report also provides information about the valorisation of the research. The Faculty actively aims at making research results available through start-up companies, publications and patents, and their application in products, processes and services, mainly by industrial partners.

Assessment/remarks
The Committee noted a very high degree of relevance of the research for a wide range of extremely important issues and aspects in society, from robotics for medical surgery to low pollutant combustion, advanced materials, sensors, and actuators for smarter purposes. The Faculty directs a substantial part of its research efforts to the short-term as well as the long-term needs of Dutch industry, and thereby to Dutch society. The Committee was pleased to note that the programmes of the Faculty indeed place great emphasis on national as well as international societal relevance.

3.5 Vision for the future

The previous Review Committee had expressed its concern that the division into departments may have erected barriers to contacts and synergies. The Faculty was advised to ensure the departments are headed by leaders with a clear mandate and research direction.

The previous Review Committee also noted that part-time professors from industry can bring synergy, but they should not lead programmes, since their presence at the University was too limited. Now, all programmes are led by full-time professors.

The 3mE Faculty provided a SWOT analysis from which a strategy for the next period was extracted. The strategy for the upcoming period is divided into a research portfolio, education, research funding, research staff, valorisation and facilities.

Assessment/remarks
The division into departments seems not to have caused problems for contacts or collaborations within the Faculty. On the contrary, the Committee observed that the leadership given to department chairmen has stimulated strategic planning and promoted a clear vision for the future of the Department in some cases. On the other hand, the Committee is concerned about the many vacancies in the departments and the reports about losses of Faculty members to foreign universities and unsuccessful recruitment attempts for replacements. It was told that the main reason for these difficulties lies in the limited autonomy of the Faculty to decide on salaries. An adequate remuneration is essential to attract top scientists with established recognition on the international level. The Committee believes that, in response to this situation, the Faculty should develop innovative means to fill these vacancies. This also holds for the recruitment of female staff members. One of the measures to be envisioned, but not the only one, is the provision of attractive start-up packages. Another concern of the Committee is the situation of associate professors, who cannot independently supervise PhD students, unlike the situation in most other international universities.

3.6 PhD training and supervision

The University considers an excellent doctoral education one of its priorities. TU Delft set up a Graduate School in 2011. On 1 January 2012, 3mE launched the 3mE Graduate School as part of this university-wide Graduate School. All new PhD students become members of this Graduate School, which offers a training programme that consists of three parts:

- Discipline-related skills
- Research skills
- Transferrable skills

Besides training the PhD students, the Graduate School also offers workshops and training for supervisors and PhD mentors. An administrative system has been set up by the university to closely monitor the progress of the PhD students.

The success rate in 2012 (< 5 years) was 38%, and the target is 60% by 2020. The Faculty considers the Graduate School to be instrumental in reaching the 60% target.

Assessment/remarks
The Graduate School seems to work well. PhD training is well-structured and tailored to the needs of the students. In general, PhD students were positive about the guidance received. However, the students suggest to critically review the general courses given in the Graduate School. They observed a difference in quality between general courses and discipline related expert courses.

Graduating without a delay seems problematic sometimes. The fact that many of the PhD students are part time students aggravates this situation. In order to finish the theses in time and make the results publicly available while they are fresh, more public investment is desirable.

General conclusion

The Committee confirms the high, internationally recognized quality of research at the 3ME Faculty of Delft University of Technology. It was impressed with the enthusiasm of many of

the Faculty members and staff members for their work. This is an indication of a good working environment.

The Committee recognizes that the involvement in industrial projects has merit and contributes to the funding since public resources have been reduced. To stay at the top, however, the Faculty should strengthen the fundamental aspects of their more applied research.

In summary, these are the most important recommendations to be made:

- The Faculty members should target their research to those areas where they have developed a particular expertise and not try to expand into new areas.
- The Faculty should develop innovative means to limit the loss of good people and avoid long vacancies, especially of chair positions. This also holds for the recruitment of female staff members.
- The policy of the Faculty should provide stability and minimize reorganizations.
- There should be a better balance between industrial and long-term fundamental research in order to reduce potentially negative impacts of industrial funding on the latter.
- There should be more institutional support for acquiring competitive European funding.
- The collaboration with the other technical universities in the Netherlands should be encouraged further.

3B Department level

3.B.1 Department: BioMechanical Engineering

Department leaders: Prof. dr J. Dankelman
Research staff: 58.2 fte

Assessments:	Quality:	2
	Relevance:	1
	Viability:	3

Brief description of the Department

The Department of BioMechanical Engineering coordinates research activities that apply Mechanical Engineering techniques - including experimentation with human volunteers, mathematical modelling, numerical analysis, and mechatronic design - to understand and facilitate physical interaction between humans and technical systems. Special attention is paid to measuring, modelling and exploiting the biomechanical and neuro-mechanical properties of humans, both as a scientific goal in its own right and as a means to optimize human-machine performance.

Quality

Overall, this is an energetic and innovative Department, demonstrating excellent growth in research funding, personnel, and productivity (as evidenced by papers, patents and spin-off companies). Through the vehicle of part-time (0.2 FTE) appointments, collaborations have been established with prominent groups both nationally and internationally.

Two of the four programmes are highly innovative, productive, and prominent. The remaining two programmes are somewhat eclipsed by the excellent performance of the first two. The application of mechatronic and robotic technologies to health-care and medical devices is emerging as one of the major innovations of the 21st century. Personnel from this department are internationally known and contribute at the forefront of this field.

Relevance

The societal relevance of this Department's research is unimpeachable, both in the short term (improvements in clinical procedures) and long term (deeper understanding of human performance and its limitations). The need to care for a steadily aging population is a major challenge for all "first-world" countries. Technology offers a means to improve the quality of care (e.g. through better diagnosis and less invasive procedures) while simultaneously reducing cost (through appropriate deployment of automation). This department has recognized this opportunity and tackled this challenge with success.

Viability

The viability of the programmes in BioMechatronics & BioRobotics and Medical Instruments is excellent. They are led by an energetic and visionary Faculty, with clearly articulated plans to capitalize on future funding opportunities.

The viability of the programme in Vision-Based Robotics is less clear. Though some activities are of top caliber, such as those focused on robot design and dynamic locomotion, seamless integration with other programmes in BioMechanical Engineering has not been achieved. The impending retirement of Professor Jonker presents both a challenge and an opportunity: the challenge to find a suitable replacement, the opportunity to think broadly in appointing a successor who could direct this programme's activities to complement and better align with the central mission of the Department.

The viability of the programme in Biomaterials Technology is also unclear, though it was noted that this programme was only recently moved to the BioMechanical Engineering Department from the Materials Science and Engineering Department. The present senior Faculty vacancy in this programme is of concern, though it may also present an opportunity to re-direct the programme's activities to better integrate with the central mission of the Department.

The Committee heard about the new educational programme in Clinical Technology. It suggests to carefully monitor that the setup of this educational programme not interferes with other programmes and research. An early review to assess the long-term impact and viability of teaching Clinical Technology may be wise.

Sub-programmes in the Department

- *BioMechatronics & BioRobotics*

This is a strong and highly innovative programme. Its emphasis on diagnostic robotics is clearly distinct from and complementary to other programmes in the Netherlands on rehabilitation robotics. The work on 4D electroencephalography is world-leading. It would be helpful if the researchers would articulate how their efforts complement and amplify other related activities (in the Netherlands and worldwide).

- *Medical Instruments*

This is a strong and highly innovative programme. Although the benefits of providing haptic feedback in minimally invasive and/or robotic surgery remain unclear at present despite extensive clinical experience with robot-assisted surgery, this may reflect the limitations of the present technology which this group aims to redress. The work on steerable needles and minimally invasive catheters is excellent. Though it may be a significant challenge, if this group could quantify how the limited performance of existing haptic feedback has compromised its benefits, that is likely to have worldwide impact

- *Vision-Based Robotics*

The novelty and potential impact of this programme is difficult to assess due in part to the already large and growing volume of competitive activities worldwide, both in service robotics and dynamic locomotion. The medical/healthcare applications emphasized transfer, tremor and dementia. Though this is laudable, the considerable practical problems of translation were not convincingly addressed. A careful assessment of the present state of practice and the remaining outstanding challenges would be wise to ensure this programme could develop a distinctive identity.

- *Biomaterials Technology*

This programme emphasizes metals functionalized to improve compatibility and integration with biological cells and tissues. Though it has the potential for excellent synergy with Medical Instruments, this has not yet been achieved. Bio-functionalized metals have a

significant potential, but the novelty of applications such as drug-eluting stents is unclear. A target application that would distinguish TU Delft has not been identified. A clear focus and vision for future growth was not articulated. An appointment to fill the present senior vacancy may be an opportunity to rectify this.

Overall conclusion

Overall, this is a strong and energetic department, demonstrating excellent productivity and prospects for future growth and prominence. The activities in Vision-Based Robotics should perhaps be re-focused to better align them with the core mission of the Department. The recent addition of the programme in Biomaterials Technology has not yet been fully integrated with the core mission of the Department. Pending new hires provide an opportunity to address these weaknesses.

3.B.2 Department: Delft Centre for Systems & Control

Department leaders: Prof. dr ir H. Hellendoorn
Research staff: 42.0 fte

Assessments:		
	Quality:	2
	Relevance:	2
	Viability:	2

Brief description of the Department

The Delft Center for Systems and Control aims at contributing to fundamental aspects of dynamic systems and control as well as advancing innovative and high-tech applications in cooperation with relevant industrial and academic partners. Control theory is a quickly developing science. The complexity in design and operation of controlled systems is increasing tremendously. This requires a computational system theory for synthesis and real-time implementation that enables the integration of model-based control with system identification for multivariable and large-scale systems. The research area of DCSC covers modelling, identification, control, and optimization of complex dynamic systems in engineering, science, and technology. In addition, the Department develops methods for the analysis, synthesis, and real-time implementation of advanced control systems with applications in robotics, mechatronics, adaptive optics, wind energy, and transportation and infrastructure systems.

Quality

This Department has become recognized worldwide as a major player in some important and innovative niche domains, especially for large systems and systems with complicated dynamics, requiring computationally efficient algorithms. The control design methods used in this Department are always based on dynamic models, obtained via direct or indirect identification or physical modelling. As such, its research covers the main aspects of the field of control engineering, while limiting itself to some important niche domains for the theoretical research and for the applications, especially the very timely 'smart' applications like transportation, energy, and optics. The fact that all the groups develop theory towards efficient algorithms and then applications closely matching this theory is especially appreciated, and constitutes the very successful 'business' model of this Department. One point that came up during the discussions, and that the Department should keep in mind while selecting its applications domains, is that control engineering is not only about the design of control loops for existing systems, but also about designing systems for controllability. As one member of the Department pointed out during the discussions, the ultimate goal should be to use smarter controls for designing cheap and reliable systems.

The senior members of the Department have built up a very good reputation based on innovative contributions to fundamental research in systems and control theory, and on applications that validate their theoretical contributions. The Department has been able to attract some very promising young staff members as testified by the five VENI personal grants over the period of review. Very little information was provided on the recent work of tenured staff, who are not yet full professors. The impression was given that, with some exceptions, they do not get a lot of visibility, and the Department is advised to make better use of their expertise. Encouraging these tenured staff members, not yet full professors, to

build up their own research domain might combine the benefits of the current more hierarchical and coherent structure of the Department with the advantages of its previous flat structure.

The CWTS report shows that the output of the Department in this respect is very good, with a quality well above average. A more significant aspect is the "best paper" and best thesis prizes which have been won by a number of the staff members and students. This shows outstanding quality of research.

The transfer of knowledge to society as a whole is very good. Except for the ICR group, very few spin-offs were mentioned. However, the Department is very successful in establishing contacts with Dutch government agencies and with important technology-oriented companies, including large multinationals. These contacts (and contracts) can be further extended via participation in Horizon2020 projects.

The training of master and PhD level students is very good, as confirmed by the doctoral students themselves and the quality of their output. The DISC School obviously plays a major role here, and the support for this very efficient tool for education should be maintained and if possible extended even further. Some PhD students, especially those working in industry, take a very long time to complete their thesis, and there is a need for more careful follow-up of them. Some doctoral students also expressed concern about their uncertain future career. Although the Department cannot change this external problem, it should be taken seriously in order to keep attracting top-level candidates for doctoral research.

The Department seems to have satisfactory facilities for experiments that are necessary for validating the theoretical results obtained by the researchers, both for physical experiments in the robotics and optics domains (and in cooperation with other departments, also the wind energy domain) as well as for virtual "detailed simulations" experiments. The choice of whether to invest in physical laboratories or virtual laboratories seems to have been made judiciously. These experiments are necessary for validating theoretical results and for transferring knowledge into expertise that can be valorized.

Relevance

Some of the work on learning for robotics has led to spin-off companies that provide useful societal contributions. The applications to smart traffic, control of wind turbines, and other smart systems (such as the planned work on smart buildings) are potentially of very high societal relevance, since these smart controls will lead to more reliable, more sustainable and cheaper systems. However, the results remain mostly at the level of prototypes, with a lot of promise for valorisation but no actual valorisation so far. In many cases the "legal uncertainty" hurdle does indeed make it very difficult to translate these smart systems into products that are currently acceptable to society. The Committee encourages the Department to increase its participation in the public debate in order to explain the advantages of these systems to society as a whole. The work on smart optics in the short term has the prospect of significantly contributing to scientific progress, thus indirectly leading to societally relevant results.

The expertise of the Department is transferred locally and internationally via a very successful master's programme and via the careful supervision of a large number of PhD students. The growth of the master's programme could be a danger if it takes too much time away from the research activities of the Department. The Committee therefore encourages the Department

to ensure that quality is preferred over quantity in this educational activity, taking into account the external political and economic constraints.

Viability

The Department has a stable base for research funding, and its domains of expertise should be well matched to the topics that will dominate the Horizon2020 programme of the EU. It is of course important that the full professor vacancy is filled in such a way that the new theoretical research topics, and the corresponding applications, also can attract sufficient support. The Committee would like to encourage the Department to keep an open mind in terms of topics for this full professor position, but to make sure that the new full professor has a very high standard in terms of both theoretical research quality and significant applications that complement the current specialization of the Department.

The Department has very good connections to the Dutch and European industry, and to academic partners internationally. The connections to industry outside the Netherlands can be reinforced further via the participation in European projects (like Horizon2020). This may enable the Department to increase its budget, which over the period of review remained "too stable" for a Department with these high ambitions (of course the financial crisis must be taken into account here, but some other groups within 3mE of similar quality seem to have been more successful in increasing their budget). The Committee would also like to encourage the Department to make sure that all its members, and not just the full professors, actively participate in the search for new research grants and funds, potentially broadening the scope of fundamental and applied topics.

The Department obviously has a significant problem in keeping some of their promising young top academic researchers at TU Delft. It is clear that part of this problem is beyond the control of the Department, but the Committee encourages the Department to take all possible steps to make the research environment as attractive as possible for young researchers, within the tight financial bounds they face. Giving a lot of freedom to all tenured staff seems important in this respect. This would probably increase the chances of getting promising VENI project holders to remain at DCSC at the end of their grant period.

Sub-programmes in the Department

- *Hybrid and Distributed Systems and Control*

This group performs top-level research on distributed and hierarchical control of large hybrid systems, using several modelling frameworks (from automata over (max,+) to switched linear systems and complementary linear programming), and has been very successful in proving the applicability of these theoretical developments to timely applications like smart transportation, power and water networks, and others. This research will form a perfect base for "extending the range of current methods of hybrid systems" for large and hierarchical plants. The future of the group is therefore very promising. Some points of attention in planning this future development might be:

- The statement in the self-evaluation report "extending the range of applicability..." is a bit vague, so it is important to think carefully about the future directions for these extensions before hiring new staff, or searching for new contracts.
- Ensure that all members of the Department are involved in this extension, and can contribute to the best of their abilities.

- Keep in mind the importance of provable performance guarantees, which require expertise in formal methods (this issue has become more pressing since the recent departure of an assistant professor with expertise in this field).
- The intention of focusing on "smart buildings" as a future applications domain (as expressed in the self-evaluation report) is very promising, but was updated during the discussion to "cooperative smart buildings" (isn't this then "smart cities"?). Clearly, careful thinking is needed in order to select this novel applications area: which other groups in DCSC, 3mE or outside should one cooperate with in order to successfully enter this field? Which fundamental research topics of the group is this choice based on?

- *Numerics for Control and Identification*

This group performs top-level research, applying broad expertise and innovative theoretical developments on algorithms for large systems to important applications: smart optics and vibration control for wind turbines. The quality of the output is proven by the significant publications produced by the group, by the prizes won by the group members, and by the successful cooperation with other faculties (mainly aerospace and physics at TU Delft, but also many prominent groups worldwide). Moreover, the group has become a leader of major research projects that other Dutch universities participate in. This cooperation is useful both for the combined use of laboratories and for the development of novel ideas via cross-fertilization. One risk involved in the large number of cooperations is that there may be a lack of focus, by trying to do everything in the field of smart optics. The Committee encourages the group to carefully consider which application domains of smart optics they want to become world leaders in, because it is not possible for a group of this size to cover all of this wide field. The Committee also highly values the work on vibration control for wind turbines.

- *Intelligent Control and Robotics*

This group has developed top-level theory and applications of many artificial intelligence, heuristic learning, and heuristic optimization tools, mainly directed towards robotics applications. The range of topics under consideration is very broad, and there might actually be a problem of spreading its expertise too thinly. Moreover, the group has invested a lot of time in setting up and initiating the operation of the TU Delft Robotics Institute (of which the head of the ICR group is the scientific leader), and at the same time setting up a major lab (also for TUD Robotics Institute). This has hampered the publications output to some extent, not just in numbers but also in citations (as compared to the very high output of the group members in the 1990s). Nevertheless, the output of this group is still very good. There are also lots of research contracts with industry, and a number of spin-off companies have resulted from their work. The cooperation with other teams participating in the TU Delft Robotics Institute and the related laboratory promises to start producing novel results in the near future.

The broad scope of the theoretical approaches and the wide range of applications under consideration in the TU Delft Robotics Institute might lead to a lack of focus of the ICR group. In fact, there is insufficient focus in the description of the current interests in the self-evaluation report. The Committee therefore advises the group to carefully select a subset of tools for the fundamental research work, and a subset of robotics applications to which the selected fundamental tools are significantly applicable. In particular, the long-term prospects of robotics (say with a 10-year horizon) should be kept in mind in order to conduct this selection of topics. While the current work on μ-UAVs is very interesting, the way robotics will evolve over the next 10 years will probably be more towards service-oriented robotics teams (e.g. for medical support or other forms of helping people). In order to ensure the long-term relevance of the group, this evolution should be carefully monitored.

Overall conclusion

Very good research is being carried out by the members of all three groups of this Department, with a good mix of theory and closely related applications. The choice of the Department to focus on a limited set of fundamental theoretical problems, of high relevance at the current time, and to work in parallel on a carefully selected set of application fields to which the theoretical results are very suitable, is strongly supported by the Committee. It is important that the Department critically assess from time to time whether novel developments in their theoretical work or novel technological developments require dropping some application areas or adding new ones. These team discussions on changes in the application areas should find a good compromise between maintaining ones in which the Department has built up a lot of expertise and entering new, more timely application areas. The current theoretical and application topics show the correct level of complementarity, yet provide enough synergy among the different application areas to create interesting collaborations among the different teams in the Department. This synergy should be maintained at all times.

This successful "business model" of the Department – starting from the fundamental research expertise of its members in algorithms and applying these algorithms to carefully selected applications - can only be maintained if all members of staff are of very high quality, and are good team players at the same time. This implies that careful attention should be paid to filling vacancies with top-level researchers, who at the same time fit in well with the current members of the Department. This is especially important for the full professor vacancy. The Committee wants to emphasize that the domain of this opening should not be defined too narrowly. Besides non-linear and adaptive control systems, the Department could also consider more forward-looking theoretical subjects like networked control (where the issue of communication failures or communication delays enters the picture), very large networks (related to the "big data" buzz word mentioned in the self-evaluation report), prediction for large systems (think of weather forecasts for smart energy networks), to mention just a few possibilities. Each of these topics seems to have a good synergy with some of the work currently done in the Department.

The Committee realizes that sufficient expertise must be maintained in the classical control areas, to ensure that teaching requirements are always met and for research-related reasons. It is important that new staff members (esp. the new professor to be hired) "know" the classical theory well (as is the case for the current staff), while doing research on novel control approaches with the corresponding novel applications.

Cooperation and complementarity with other departments in 3mE, other groups in TU Delft and other control groups in the Netherlands (the part-time appointment of staff from other Dutch universities can help with this last form of cooperation and synergy) are crucial to maintain the high level of performance of the Department, given its limited size.

3.B.3 Department: Process & Energy

Department leaders: Prof. dr. ir. B.J. Boersma
Research staff: 61.6 fte

Assessments:	Quality:	2
	Relevance:	2
	Viability:	2

Brief description of the Department

The research in the Process and Energy Department (P&E) focuses on process and energy technology within a mechanical engineering context. The research topics range from fundamental to conceptual and applied in nature. The main objective of the research is to develop more energy-efficient processes for the conversion of energy and mass in a wide variety of settings, in close collaboration with industry.

Over the past few years the coherence of the Department was increased by the acquisition of projects in which more than one chair was involved. The Department considers these projects important, since the combination of fluid mechanics, thermodynamics, and energy and process technology will have added benefits. To foster this purpose, new tenure-track researchers are positioned more loosely 'between' the chairs.

Quality

The bibliometric study shows that the scientific impact of the Department is above world average. This is the result of a significant number of publications in ISI-indexed scientific journals, and occasionally results are published in high-impact journals.

The research is strongly driven by industrial needs and applications. It is strongly focused on experiments, and in two subgroups large pilot facilities enable the transfer to industrial applications. A clear vision based on the experience and the expertise of the involved group leaders is not fully evident. This common vision could strengthen the synergetic effects among the chairs and lead to novel methods and technologies.

The research in the Department is supported by national and international funding agencies, direct funding and industrial research contracts.

The academic reputations of the chairs of the participating programmes allow the Department to attract many guest visitors. The Department (co)hosts international workshops and conferences. This highlights the fact that the Department is very engaged in disseminating knowledge, methods and technologies, which helps convince interested industrial partners to collaborate. One positive recognition of this status is the ERC grant awarded to one chair. More European-wide collaborations and grants can maintain or even improve the strong position of the Department in several research areas, especially the Fluid Mechanics and the Energy Technology groups.

Relevance

The Department is attractive for industrial partners, specifically since process technology in the Netherlands has a very long history. Not only applied research, but also many fundamental research projects have roots in applied or industrial problems. In addition, the Department aims at interacting actively with diverse stakeholders in society.

In this "after nuclear power period", energy-related methods and technologies are of primary relevance. The research should lead to sustainable solutions. A clear focus on the research in this area and its actual and future relevance is lacking, however.

Societal impact is evident in the training of the next generation of process engineers and in the investments of industrial partners. Furthermore, the Department produces professional publications and participates in the working parties of major associations.

Industrial partners directly use the knowledge generated in multiple projects.

Viability

The Department envisions a number of trends concerning the growing energy need with an continuous decrease in the availability of natural resources. It considers itself in an excellent position to make major contributions in this area. Funding opportunities are envisioned from the government (funding agencies) and industry. However, a certain amount of funding for a kind of blue sky research in the energy field is strongly recommended to compete with very strong international research groups in the energy area.

The chair holders are relatively young, and thus there is the potential to grow even further in the future.

Sub-programmes in the Department

- *Fluid Mechanics*

This programme mainly focuses on gasses and liquids and mostly experimental research. It covers the range from micro to macro, but the focus on the micro area is barely evident to the Committee. The experimental techniques are mostly based on non-intrusive laser optics. The research is more opportunity-driven than based on fundamental research questions. The cooperation with chemical engineers on micro-systems, with the maritime group and within the Department is acknowledged. It is strongly recommended to strengthen the fundamental research based on a clear vision.

- *Energy Technology*

This programme focuses on a diverse field of more or less traditional energy technologies. It has some relevant activities in combustion, but the need for large-scale installations for the research in this area could not be demonstrated by the programme. The uniqueness of its experimental research lies more in the size of the units than in its experimental technique or its fundamental research. A clear focus in the research field is missing. In order to differentiate itself from competing research groups, the bridge from the fundamental work to the possibility to test new ideas in rather large units must be highlighted. The need for large-scale experiments is not obvious. The cost of these units is high, and therefore the need for them must be questioned in line with the vision and strategy of the subgroup.

The renewable source being investigated is biomass. Collaboration between all the renewable energy technology groups at TU Delft is highly recommended. The programme is in a transition phase, which creates an opportunity to define unique areas to strengthen the fundamental research instead of optimizing known components in energy technology.

- *Intensified Reaction and Separation Systems*

This programme is very successful and addresses relevant questions in the area. The necessary exchanges with chemistry and chemical engineering at the University are already established. Fundamental research on reaction engineering allows the appropriate design of highly efficient processes in several fields in chemistry. Internationally, the research is highly respected.

The areas of research are widespread. It would be helpful to have a clear vision for this programme, because process intensification covers a large field.

- *Engineering Thermodynamics*

The programme deals with a wide range of questions from more applied areas like heat pumps to fundamental research on molecular thermodynamics and complex fluids. Its focus lies overall in the minimization of entropy production. Due to cost cuts, an interesting area on experimental high-pressure thermodynamics has been abandoned although it is becoming increasingly important, e.g. in heat exchange at power plants. The group is highly integrated in national and international programmes. The publications are of high quality.

Overall conclusion

In summary, the Department is very engaged not only in answering scientific questions in the energy and processing area, but also in demonstrating machines and processes and applying the fundamental results. The process intensification initiative and its research are highly respected worldwide. The thermodynamic fundamentals are extended in relevant fields. Turbulence and complex fluids might be strengthened by focussing on defined fundamental visions. The energy technology sector is crucial in this Department, but the focus must be clearly directed to basic research instead of large pilot facilities. Open positions are an opportunity to make this change.

3.B.4 Department: Precision and Microsystems Engineering

Department leaders: Prof. dr U. Staufer
Research staff: 25.5 fte

Assessments:	Quality:	2
	Relevance:	2
	Viability:	1

Brief description of the Department

Precision and Microsystems Engineering (PME) focuses on the integration of fundamental and application-inspired research on mechanics, micro/nanotechnology, mechatronics, and advanced manufacturing. Computational design methodologies are a key component of its activities. PME investigates the underlying physical and engineering principles for manufacturing and ultimately aims to reach concept validation by implementation. It places special emphasis on introducing the achievements of nanoscience and associated precision tools into its Mechanical Engineering solutions.

Quality

PME is a well-structured department that exhibits a cohesive strategy. The Committee found this Department to be exemplary within the Faculty for behaving the most like a true department in which resources are pooled between professors in order to move towards fulfilling a department-wide strategic vision. The relatively large number of joint publications among research programmes within the Department also indicates that the structure of the Department is successful in fostering interdisciplinary research. The overall scientific output of the Department is at an excellent level, given the focus area. The Committee noted a number of publications by members of the Department in high-impact journals for their respective fields. However, there did appear to be a somewhat uneven distribution of publications among the Department members. The Committee agrees that publications are an important indicator that show the achievement of key scientific results. The lack of publications in a particular area can be an indicator of lower impact scientific endeavors that must be critically evaluated by the Department for possible termination. The Committee also recognizes, however, that some activities that do not yield strong publications may be of significant interest from an industrial or educational perspective.

Department members interact on national and international levels with many of the top groups in their respective fields, such as CERN, Imperial College, MIT, TU Munich, ETH Zurich, ASML, Bosch, Philips, etc. This is a further indicator of world-class research programmes. Various academic indicators such as keynote lectures, invited talks, and journal editorial board memberships also support the Committee's opinion of a high-quality Department.

Relevance

The focus areas of PME are highly relevant to Dutch society and in line with many important industries within the Netherlands. The Department serves as an important anchor for Mechanical Engineering at TU Delft and provides fundamental expertise in mechanics, dynamics, and precision mechanisms. Mechanical Engineering at TU Delft cannot thrive without a strong performance by PME in both research and education.

Viability

During the review presentation, PME demonstrated a cohesive vision that leads the Committee to believe that the Department will continue to follow a viable strategy in the future. The desire to create an Industrial Partnership Programme (IPP) is to be commended and shows the kind of strategic thinking that top research groups must pursue at times. There are risks in creating a programme of this type, such as how intellectual property rights will be handled and how industrial competitors can cooperate. The Committee believes that if the Department is convinced that this type of programme is viable, the TU Delft administration should make every effort to support the creation of an IPP. This support could be in the form of additional staff members or in making Department research reserves available to initiate the programme at a strong level. The Committee would also encourage the Department to give strong consideration to applying reserve funds to create attractive start-up packages for new hires.

The Department appears to be well connected to various research facilities at TU Delft and across the Netherlands, including the Delft Centre for Mechatronics and Microsystems, MicroNed, NanoNextNL, MinacNed, and Holland Instrumentation. The leadership the Department members show in ensuring that access to properly running major research facilities is in place bodes well for the future viability of the Department.

The Department is encouraged to strengthen its strategy to add female staff members and to increase the number of female students in order to further improve the Department's future viability.

The Committee was pleased to learn the Department has been able to handle a significant increase in teaching duties while minimizing a negative impact on research activities.

Sub-programmes in the Department

- *Structural Optimization and Mechanics (SOM)*

The direction of the sub-programme is appropriately motivated based on existing expertise and emerging progressive technologies. Topology optimization is well suited for additive manufacturing. The Department's vision to expand this activity towards a more multidisciplinary approach that includes fields from material science, thermal modelling, structural modelling, etc., is convincing and to be encouraged. There is a danger here, which SOM is aware of, that additive manufacturing is currently considered to be somewhat over-hyped by the press, and there is a lack of material options in creating structures. However, given the possible impact this area may have on manufacturing in the future, it is sensible to continue to develop strong efforts in this area. Mechanics is an absolutely essential discipline within any Mechanical Engineering Faculty, and the Committee was impressed by SOM's ability to educate large numbers of students in this fundamental field.

- *Mechatronics System Design*

While this sub-programme is heavily influenced by industry, the Committee noted that strong peer-reviewed publications have resulted from activities in this area. Traditionally, Europe has been a leader in precision mechatronics, and the Committee was pleased to see this group helping to keep TU Delft and Europe as a whole at the forefront of this critical area.

- *Micro and Nano Engineering*

In many ways this sub-programme is particularly well poised to enhance the Department's and the Faculty's scientific reputation. World-class work in scanning probe technology led by Professor Staufer is being pursued, and some very impressive scientific publications have come out of this group. The materials science and processing background of Professor Janssen is especially interesting for the MNE programme and will almost certainly lead to fruitful interactions among programme members in the future.

Overall conclusion

Precision and Microsystems Engineering is an essential department within the Faculty from both research and educational perspectives. The Department is well structured and led by a cohesive team of professors. Its scientific output is of a very high quality and a sufficiently high quantity. With a large reserve fund, open staff positions, and a reasonably positive outlook with respect to laboratory space, there are excellent opportunities for this Department to rise to an even higher level of performance over the next five years.

3.B.5 Department: Materials Science and Engineering

Department leaders: Prof. dr I.M. Richardson
Research staff: 48.3 fte

Assessments:	Quality:	2
	Relevance:	2
	Viability:	3

Brief description of the Department

The Department of Materials Science and Engineering performs research on the synthesis and characterization of materials. This work includes the fundamental investigation of the relations between atomic-level structure and material properties, as well as optimization of the properties for specific applications. It maintains a special focus on the study of metals, including their microstructure, extraction, recycling, joining, mechanical behavior and corrosion. It makes extensive efforts in theory and simulation, and has a variety of projects in the area of surface and interface engineering. It recently developed a project in the study of materials in art and archeology.

Quality

Overall, the quality of the research in the Department is very good. Some of it is highly innovative and world class: their development of 3D imaging for the *in situ* study of the evolution of microstructure has given a whole new impulse to this classic field. The Department has an excellent corrosion group, which has developed innovative local probes of the corrosion process and maintained essential competence in metal corrosion - a field unjustly neglected in materials research worldwide. It has a strong group of theoreticians and simulators who cover a wide variety of techniques and applications, and their venture into the materials science of art has been very successful. The members of the Department have a strong publication record, with articles in the top journals in the field.

The Department maintains essential facilities for the synthesis, imaging, surface analysis and testing of materials. It has closed down its casting facility and acquired new synthesis capability in the form of spark plasma sintering. It also boosted its 3D imaging capability by the joint acquisition of an atom probe with TU Eindhoven.

Relevance

Materials research is of obvious societal relevance: 'everything is made of something', and metals, for which the Department has established a strong reputation, are of enduring economic relevance. The ties with Dutch and international industry are strong and of long standing. The new art and archeology initiative is of obvious relevance to the Dutch and international art world, and has already provided some key instrumentation.

Viability

The MSE Department has undergone a series of reorganizations. The previous assessment report called for a period of stability that would allow the Department to make long-range plans. Instead, the past six years have seen substantial changes, in particular the reassignment of a number of staff members to other departments. In one case (Janssen), this appears to

have led to a successful integration into the new department (PME); in the other (biomaterials), the transplanted group is still trying to find its feet and has not yet developed synergies with the rest of its new department (BioMech). The obvious result for the MSE Department is a loss of personnel and resources. The remainder of the Department represents the distinctive intellectual core of materials science: the science of microstructure. It maintains facilities that are essential for the rest of materials research at TUD, and its members contribute intellectually to materials efforts across the university.

The Department has done well in maintaining specialist competence in metals research, and will continue to do so in the future. Since many materials science departments worldwide have let their competence in this important area slip, the Department should continue to exploit this comparative advantage. Metals continue to have great economic importance, and because of their reproducibility and the wealth of existing scientific knowledge about them, they remain the prime materials for fundamental studies of phase transformations and mechanical behavior.

For years, the Department has benefited from the substantial support provided by M2i (earlier the NIMR), which gave a sustained impulse for metallurgical research, and established a unique model of collaboration with industry on pre-competitive research that maintained a healthy balance between fundamental work and industrial applications. The restructuring of M2i support model has amounted to a substantial cut in funding for the Department, but given the close ties that many of the Department members have with industry, it should be possible to establish new forms of collaboration and support.

The key element in the viability of a department is its ability to attract new talent. The MSE Department's search for an appointment in materials for extreme conditions did not produce a suitable candidate. Nevertheless, this general area remains one of economic and intellectual importance, and there is reason for optimism that in a few years a strong new staff member will be appointed.

Sub-programmes in the Department

- *Metals Processing, Microstructure and Properties*

This programme covers a wide range of research on the life cycle of metallic materials. It is conducting interesting work on primary production through its connection with Tata Steel on the HIsarna process. The 3D imaging and diffraction work, in particular the *in situ* work on phase transformations, remains highly innovative. The planned focus on nucleation is well chosen, since this phenomenon remains one of the most important yet least rigorously treatable ones in the physical sciences. The corrosion work continues to exploit its advantage in microscopic probing of electrochemical processes. There is close collaboration with Professor Terryn's group at the VUB, and Dr Mol has successfully continued to develop the area. The welding work has moved from an emphasis on processes to one on microstructural changes, which integrates it more closely with the rest of the activity in the programme. The group is well placed to participate in the European initiatives on recycling and substitution of rare elements.

- *Virtual Materials and Mechanics*

The three principals in this programme are excellent theoreticians and simulators with complementary skills in ab initio methods, molecular dynamics, Monte Carlo, and mechanical simulations from discrete dislocations to finite element. The group works on a large variety of projects, many in collaboration with experimentalists inside the Department as well as outside

(e.g., graphene buckling). They have interesting plans to explore the use of GPU computation. The group should remain viable upon Professor Thijsse's retirement if, as indicated, Lucia Nicola's expertise continues to broaden to include the molecular dynamics work.

- *Materials in Art and Archaeology*

This is a fairly new programme that was started about six years ago. It has been very successful in making links with the art history and archaeology fields. The development of new analysis tools (new to the art field), such as a portable X-ray fluorescence analyser, has been well received, and this line of work is a clear niche where materials scientists can make unique contributions. Given the strong start and the fertile environment of art history and preservation in the Netherlands, this programme should continue to flourish.

- *Surfaces & Interfaces*

This group works on a rather diverse range of topics. Some of them are quite interesting (such as self-healing thermal barrier coatings), but there is little coherence in the work. Part of the reason is that the programme does not have a leader at this time to give it the necessary direction. It is possible that the anticipated appointment in materials for extreme conditions will provide such leadership. It should be recognized that this group also maintains very high-level expertise in surface analysis and diffraction that are essential to the overall materials effort in the Department and the University.

Overall conclusion

Materials Science and Engineering is an essential part of many branches of engineering, and MSE is therefore a key department in TU Delft. This Department has some top-notch staff members who do world-leading research. It has strong ties with industry, both intellectually and financially. It has been plagued, however, by continuous reorganizations and deserves a rest, so it can develop and execute its strategic plans, which are sound and promising.

3.B.6 Department: Maritime & Transport Technology

Department leaders: Prof. dr ir G. Lodewijks
Research staff: 36.5 fte

Assessments:		
	Quality:	2
	Relevance:	1
	Viability:	2

Brief description of the Department

The Department of Maritime & Transport Technology (MTT) educates students to develop, design, build and operate marine, offshore, dredging and transport systems based on scientific methods and carry out cutting edge research based on the technology and management of the systems and processes involved.

The coherence of activities within MTT has increased by involving the four research groups (programmes): *Transport Engineering and Logistics* (TEL); *Ship Design, Production and Operation* (SDPO); *Ship Hydromechanics and Structures* (SHS); and *Offshore and Dredging Engineering* (ODE) in research focus areas: Intelligent Marine, Transport and Production Processes; Design for Service; Deep-Water Offshore and Dredging, and Innovative Design of Marine and Transport Concepts. MTT has also been involved in various initiatives across the Faculty.

Three of the four research programmes deal with the synthesis of technology, management and economy, and have close ties with industry, while the fourth, Ship hydromechanics and structures, represents subsets of fluid and solid mechanics. The former areas require significant synthesis and practical information.

The Department has been shifting from applied to more fundamental research, e.g. from the recruitment of "professors of practice" to "research professors", while maintaining a strong link to the industry with a strong industry project portfolio. Combined use of numerical models and experimental validation is an important aspect of the MTT research. This strategy has led to more journal papers and PhD candidates and graduates compared to the situation at the start of the evaluation period. The Department is part of an excellent national and international research network and is visible on international journal boards and conference committees.

The Committee had limited insight into the educational programme/teaching load, but it seems that it is worthwhile to assess the teaching load to possibly reduce it and allow more time for research.

Quality

This Department is considered to be one of the most influential research groups of its kind. However, to obtain a top score among mechanical engineering groups at large, the Department clearly needs to move towards more basic research, more full-time PhD graduates, and publishing in journals. Important steps in this direction have been taken, enhanced by changing the recruitment policy of staff members and by increased numbers of PhD candidates and journal publications, and hence better citation indices. While the total publishing activity (publications/funding) for the Department is at an average level in the Faculty, the ratio of journal to conference papers is 1:4, while for other departments this

figure is more balanced. The Department deserves credit for conference publications, especially in design and planning oriented engineering fields, which have a limited number of high-quality scientific journals, and few users who write journal papers and cite such results. MTT should also be credited for its contribution to innovation – which currently is not an explicit performance indicator.

Relevance

The Department has an excellent partnership with the vital and innovative Dutch maritime industry, through projects, part-time professors from industry, MSc and PhD candidates, meetings in different fora, societies, etc. This strong link to the industry (and probably state administrations) ensures that the many research results can be explored by the industry at an early stage.

As the only university group of its kind in the Netherlands, the SDPO, SHS and (in practice) ODE groups are unique and have a particular role of producing engineers and providing research results for innovation in industry.

The active role the Department plays in different engineering societies contributes to its societal impact.

Viability

The new generation of marine systems for transport and other ocean activities has to be based on new concepts, using distributed intelligence, combined with the application of smart components. This requires the further development of knowledge of marine systems. Given the significant national marine industries, solid research cluster by MMT and other units at TU Delft, Marin, TNO, etc. there exists a strong demand for viable marine education and research activities. There is especially a potential of new developments within the oil and gas and subsea mining industries – also under arctic conditions. Clearly, the viability of MTT depends on seizing these opportunities and contributing in cooperation with other departments at TU Delft as well as its national and international partners.

The viability of this Department is ensured by several new, active chair holders, a capable Department Head, and a government and an industry that support its activities. The economy of MTT seems to be healthy – also because of a "steady" licence income e.g. from the AxeBow development. However, it is important that chairs and other key positions, such as the one in offshore, are filled with research professors in a tenure track (rather than "professors of practice" only) as soon as possible to ensure continuity in the relatively small and vulnerable research groups. Nevertheless, a limited number of adjunct professors from industry (especially in technical-economical design and planning disciplines) and maybe to a larger extent professors from other universities or research institutes with high complementary competence could still have an important role to play. The experimental facilities of the Department as well as strategic cooperative agreements with other universities and research institutes are important issues to ensure viability.

Moreover, the viability depends on realizing the ambition to increase academic performance in the Department by improving journal publications and PhD graduation rates. Introduction of a requirement that PhD candidates should publish at least 2-3 journal papers will gradually show up in the statistics. Moreover, more PhD graduates will increase the funding.

In view of the nature of the marine and transport technologies, the Committee sees the benefit of PhD candidates in certain areas spending *some* time in industry. At the same time it is important that their research has an academic quality that TU Delft can be proud of. Being exposed to and contributing to the research culture at the university and completing the PhD in a reasonable time are important aspects of quality. The concept of "external PhD candidates" should be assessed from this point of view.

While organizational changes can create inspiration and dynamics in the Department, too many changes and vacant chairs can cause problems in settling the educational and research programmes.

Sub-programmes in the Department

All the sub-programmes (except the offshore area in ODE due to a vacant chair) in MTT have developed well since the last assessment in 2008. In the sections above, the comments about the Department are applicable to the programmes as well. In the following, some specific comments on the different sub-programmes are offered.

- *Transport Engineering and Logistics*

The TEL programme deals with research relating to the engineering of efficient and safe transport systems for cargo and people and logistics. The group is unique and has an important role to play in the Netherlands, a clear strategy and a strong international position. Increased focus on maritime transport has initiated collaboration within the Department and with other departments. The societal relevance is high. While significant progress regarding academic impact has been noted over the review period, it is still limited, and the TEL group needs to increase its academic reputation by focussing more on journal publications and turning out PhD graduates. Several examples of basic research activities have been conducted, but they appear a bit fragmented because of the very broad scope of this programme. A strategic aspect in this connection could be to identify a few carefully selected *areas* with high relevance – among the very many research areas that fall within what are denoted the focus areas of TEL - where sufficient efforts can be allocated to increase the visibility and impact of the research.

- *Ship Design, Production and Operation*

The research in the SDPO programme spans the life cycle of ship hulls and machinery, and includes design, fabrication and operation, with a focus on complex ships. The area covered by this programme is apparently very broad, requiring the integration of knowledge from many disciplines. SDPO is involved in three of the focus research areas of MTT, with a primary goal of developing methods and computer tools to support distributed multidisciplinary (early) design and engineering environments. The group has had a healthy development since the new chair took office just before the current review period started. The group has contributed to applied knowledge in the industry through its close industry links, and is improving its academic publishing and PhD graduation rate, which is still below average for the mechanical engineering field. Hence, its academic reputation should still be improved while maintaining the excellent working relationship with the industry described above. The significant increase in the number of PhD candidates and a clear publishing strategy are expected to contribute to an improved academic standing.

- *Ship Hydromechanics and Structures*

The SHS programme deals with the behaviour of ships and other marine structures in a seaway and their structural integrity, using numerical and experimental methods. The

hydrodynamics sub-programmes have excellent experimental facilities, are part of an international research network and have a clear research strategy. The plans are less clear for the structures sub-programme due to the vacancy of the chair until 2011. However, some of its activities are evident (in terms of fatigue and fracture – under multiaxial stress conditions), but the strategy for this sub-programme needs further elaboration. The economics of the SHS programme seems to be healthy. While some papers of high quality have been published, the number of such publications still needs to be increased to a stable higher level. The academic and practical impact of the research in the SHS group is very good.

The past performance of the hydromechanics sub-programme and an emerging strategy for the structures activities, the international cooperative network as well as the good outlook for funding in the ship and offshore area show the viability of the research programme. However, filling the vacant chair in ship and offshore structures in the ODE programme is important also from the SHS point of view. Future viability could be strengthened by getting involved in the deep sea mining initiative together with the ODE programme and other units within the Faculty and University. Marine operations, such as transport and lifting, related to offshore oil and gas and renewable energy (especially wind), is also an interesting area, where the Dutch industry is already a world leader. Such activities can be based on a synergy between the ODE and SHS programmes.

- *Offshore and Dredging Engineering*

The ODE programme covers structures and systems used in the offshore oil and gas industry, ocean renewable energy as well as dredging; they all utilise large, unique facilities that call for advanced multidisciplinary knowledge in the design and operation planning. The ODE programme is important and also unique in the Netherlands. The dredging chair was vacant for some time before the current chair took office just before the current review period started. At that time the group was dormant, but it has undergone a healthy development since then. Its practical relevance is very good due to its close links with the unique Dutch dredging industry, while the academic impact of the dredging research is limited and needs to be improved. Getting the chair for the offshore sub-programme in place is important for the performance of the SHS and ODE sub-programmes – to engage for instance in the significant industrial potential for renewable offshore energy, offshore oil and gas, dredging in shallow waters as well as possibly deep sea mining. Some of these industrial activities are envisaged as taking place under arctic conditions. The activities in these new areas can stimulate cooperation with other groups in the Faculty and other units at TU Delft.

Overall conclusion

MTT provides education and research in areas of significant value for the Dutch industry and society. The Department has close ties with the industry. It has developed its academic performance over the review period, but still needs to improve it by publishing more papers based on fundamental research in journals and producing more PhD graduates, while maintaining the cooperation with and funding from the industry. The significant potential for research related to e.g. marine operations in the oil and gas, renewable energy and deep sea mining sectors, possibly considering arctic operations, should be explored. Such activities may involve various units in MTT as well as in other departments. The balance between teaching load and research should be considered, possibly with the aim to reduce the teaching load. The economics side is healthy. The vulnerability of the operation of the programmes in the Department to staff members (and especially chair persons) leaving MTT because of retirement or other reasons should be minimized by properly preparing for the changes with e.g. overlapping periods.

Appendices

Appendix 1: Curricula vitae of the committee members

René Boel obtained his Electromechnaical Engineering degree in 1969 from Ghent University, Ghent, Belgium, and his Ph.D. degree in 1974 from the Electrical Engineering and Computer Science Department of the University of California, Berkeley, with a thesis on theoretical research related to stochastic control (supervisor: Pravin Varaiya). Since 1980 he was a tenured research fellow of the National Foundation for Scientific Research (FWO-Vlaanderen) at Ghent University, while also visiting several institutes abroad (incl. Bell Telephone Laboratories, Imperial College, Australian National University, Newcastle University Australia). From 2000 till 2011 René Boel was a professor of systems and control engineering at Ghent University. His research covered stochastic control, adaptive control, control of queueing systems, discrete and hybrid systems theory with an emphasis on fault detection, distributed control and coordination control for networks (including traffic control and smart grids). Since 2011 he is retired, and has an honorary professorship at Ghent University.

Neville Hogan is Sun Jae Professor of Mechanical Engineering and Professor of Brain and Cognitive Sciences at the Massachusetts Institute of Technology (MIT). He received the Diploma in Engineering (with distinction) from Dublin Institute of Technology in Ireland, and M.S., Mechanical Engineer and Ph.D. degrees from MIT. Following industrial experience in engineering design, he joined MIT's Faculty in 1979 and has served as Head and Associate Head of the MIT Mechanical Engineering Department's System Dynamics and Control Division. He is presently Director of the Newman Laboratory for Biomechanics and Human Rehabilitation and a founder and director of Interactive Motion Technologies, Inc. Professor Hogan's research interests include robotics, sensory-motor neuroscience, and rehabilitation engineering, emphasizing the control of physical contact and dynamic interaction. He serves on the editorial boards of IEEE Transactions on Neural Systems and Rehabilitation Engineering, the Journal of Motor Behavior and the Journal of Healthcare Engineering. He has been awarded Honorary Doctorates from Delft University of Technology and Dublin Institute of Technology; the Silver Medal of the Royal Academy of Medicine in Ireland; the Henry M. Paynter Outstanding Investigator Award, and the Rufus T. Oldenburger Medal from the Dynamic Systems and Control Division of the American Society of Mechanical Engineers.

Torgeir Moan is Professor of Marine Technology and director of the Centre for Ships and Ocean Structures at the Norwegian University of Science & Technology (NTNU). In the period 2002-2007 he was called the first adjunct Keppel professor in Ocean Engineering at the National University of Singapore. Professor Moan's main field of work is structural analysis and design of marine structures, with an emphasis on safety analysis. He has co-authored a book on Stochastic dynamics of marine structures at Cambridge University Press. Professor Moan has developed new methods and design criteria (standards) for offshore structures, ships, wind turbines and floating bridges and has served on accident inquiry commissions. He has supervised 68 PhD graduates. He is editor of J. Marine Structures and serves on the board of several other journals. Professor Moan has delivered about 30 keynote lectures at major international conferences and has received various awards for his research, such as the James W. Rice of ASME, Petroleum Safety Authority and Statoil awards. He is elected member of the three academies of science in Norway, and the Royal Academy of Engineering, UK as well as a fellow of the ASCE, IABSE, the Offshore Energy Center Hall of Fame, Houston as well as a Life Member, ASME. He is visiting professor of Zhejiang

University and honorary professor of two other Chinese universities. He has been involved in RAEs in Brazil, China, Finland, the Netherlands, Portugal and Sweden.

Brad Nelson is the Professor of Robotics and Intelligent Systems at the Swiss Federal Institute of Technology Zurich (ETH Zurich), where his research focuses on micro and nanorobotics. Fundamentally, he is interested in how to make tiny intelligent machines that are millimeters to nanometers in size. He studied mechanical engineering at the University of Illinois and the University of Minnesota, worked at Honeywell and Motorola, served as a United States Peace Corps Volunteer in Botswana, and then obtained a Ph.D. in Robotics from Carnegie Mellon University in 1995. He was Assistant Professor at the University of Illinois at Chicago (1995-1998) and Associate Professor at the University of Minnesota (1998-2002). He became Full Professor at ETH Zürich in 2002. He has received a number of awards, is a two-time World Champion in Robocup's Nanogram Soccer League, and is in the 2012 Guinness Book of World Records for "Most Advanced Mini Robot for Medical Use." He serves on several editorial boards, has been Department Head of Mechanical and Process Engineering, Chairman of the ETH Electron Microscopy Center, and is a member of the Research Council of the Swiss National Science Foundation.

Norbert Peters (chair) is Emeritus Professor at the Institute of Combustion Technology of the RWTH Aachen University at Aachen. Germany. He received his PhD. from the Technical University of Berlin in 1971 and became Professor in Mechanics at the RWTH Aachen in 1976. He was Visiting Professor at the University of California, San Diego, and at Sandia Laboratories in Livermore, California. He specialized in the field of combustion and co-authored over 300 papers in combustion and a monograph entitled 'Turbulent Combustion' which appeared at Cambridge University Press in 2000. In 1990 he received the Leibniz-Prize of the Deutsche Forschungsgemeinschaft as well as the Horning Memorial Award and the Arch T. Colwell Merit Award of the Society of Automotive Engineers. In 2002 he received the Zeldovich Gold Medal of the Combustion Institute. He is member of the Nordrhein-Westfälische Akademie der Wissenschaften as well as Foreign Associate of the US National Academy of Engineering. He is Honorary Doctor of the Université Libre de Bruxelles, Honorary Doctor at the Technical University Darmstadt and Honorary Doctor at the ETH Zürich. In 2001-2002 he was Full professor at Stanford University in the Center for Turbulence Research where he changed his research focus towards fundamental questions in turbulence.

Philipp Rudolf von Rohr graduated as process engineer at ETH Zurich in 1978; he then worked as research assistant at ETH Zurich for one year before he started his doctoral studies. In 1983 he received a Ph.D. from ETH Zurich. After a two year postdoc at MIT, USA he returned to ETH and served as First Assistant. From 1986 until his start at ETH Zurich as professor in 1992, he worked in an SME (400 employees) and became its CTO in 1990. He served as institute's head and at the Department as its Department head. He was a guest professor at UC Santa Barbara in USA, in 1999, at MIT in USA in 2006 and he was invited professor at the Chinese Academy of Science in Beijing in 2013. He is a member of the Swiss Academy of Technical Sciences and active in the European and Swiss Chemical Engineering Associations. In 2006 he received an honorary Ph.D. from the Slovak Technical University in Bratislava. He serves as research council at the Swiss National Science Foundation and as an expert in the Commission of Technology and Innovation. Under his guidance, 50 students have received Ph.D. degrees in his main research areas of process intensification, of plasma processes and of supercritical fluids.

Frans Spaepen is the John C. and Helen F. Franklin Professor of Applied Physics at Harvard University Division of Engineering and Applied Sciences. From 1990 through 1998 he was Director of the Harvard Materials Research Laboratory/Materials Research Science and Engineering Center. From 2002 through 2013 he was Director of the Rowland Institute at Harvard. In 2008-09 he was Interim Dean of the School of Engineering and Applied Sciences, and in 2009-12 he was Interim Director of the Center for Nanoscale Systems. His research interests span a wide range of experimental and theoretical topics in materials science, such as amorphous metals and semiconductors (viscosity, diffusion, mechanical properties), the structure and thermodynamics of interfaces (crystal/melt, amorphous/crystalline semiconductors, grain boundaries), mechanical properties of thin films, the perfection of silicon crystals for metrological applications, and the use of colloids for dynamic modeling of crystals and glasses. He is a Fellow of the American Physical Society (Chairman, Division of Materials Physics, 1992), of TMS-AIME, and of the Materials Research Society. He is a member of the National Academy of Engineering and of the Vlaamse Academie voor Wetenschappen en Kunsten In 1988 he was Chairman of the Gordon Research Conference on Physical Metallurgy, and in 1990 he co-chaired the Fall Meeting of the MRS in Boston. He has been co-editor of Solid State Physics, Principal editor of the Journal of Materials Research, and an editorial board member of a number of materials science journals.

Appendix 2: Explanation of the Standard Evaluation Protocol scores

	Meaning	Research quality	Relevance to society	Viability
1	World leading/ excellent	The relevant research unit has been shown to be one of the few most influential research groups in the world in its particular field.	The relevant research unit is recognised for making an outstanding contribution to society.	The relevant research unit is excellently equipped for the future.
2	Very good	The relevant research unit conducts very good, internationally recognised research.	The relevant research unit is recognised for making a very good contribution to society.	The relevant research unit is very well equipped for the future.
3	Good	The relevant research unit conducts good research.	The relevant research unit is recognised for making a good contribution to society.	The relevant research unit makes responsible strategic decisions and is therefore well equipped for the future.
4	Unsatisfactory	The relevant research unit does not achieve satisfactory results in its field.	The relevant research unit does not make a satisfactory contribution to society.	The relevant research unit is not adequately equipped for the future.

Appendix 3: Programme of the site visit

Day 0 : Preliminary meeting during dinner Restaurant de Waag

17.00 – 17.30 T. Baller / M.H. Sirks-Bong meeting with committee members

Day 1: April 14, 2014. Venue: Faculty 3mE, Meeting Room MSE, Tower H, 1st floor

Time	Activity	Present
09.00 - 09.45	Meeting with the Dean regarding the self-assessment	Prof. T. Baller, Dean / M.H. Sirks-Bong, Faculty Secretary
09.45 – 10.00	Reflection	
10.00 – 11.00	Dept. Biomechanical Engineering	Dept.: Prof. J. Dankelman, Prof. F. van der Helm, Prof. P. Jonker, J. Zhou (head a.i.)
11.00 – 11.30	Lab visits	
11.30 – 12.30	Four sub-programmes	BMBR: Prof. F. van der Helm, M. Wisse, A. Schoute MI: Prof. J. Dankelman, Prof. P. Breeedveld, J. van den Dobbelsteen VbR: Prof. P. Jonker, M. Rudinac Biomaterials: J. Zhou (head a.i.), I. Apachitei
12.30 – 13.00	Reflection	
13.00 – 14.00	Lunch with PhD students	BMechE: Jeroen Wildebeest, Kirsten Henken, Wouter Wolfslag P&E: Jurriaan Peeters, Jerke Eisma, Mahinder Ramindin
14.00 – 15.00	Dept. Process & Energy	Prof. B.J. Boersma, Prof. A. Stankiewicz, Prof. J. Westerweel, Prof. T. Vlugt, Prof. D. Roekaerts
15.00 – 15.30	Lab visits	
15.30 – 16.30	Four sub-programmes	
16.30 - 17.30	Reflection	
17.30 – 19.30	Dinner	

Underlined names: Head of Department

Day 2: April 15, 2014. Venue: Faculty 3mE, Meeting Room MSE, Tower A, 1st floor

Time	Activity	Present
09.00 – 10.00	Dept. Materials Science & Engineering	Prof. I. Richardson, Prof. J. Sietsma, Prof. B. Thijsse, Prof. J. Dik
10.00 – 10.30	Lab visits	
10.30 – 11.30	Four sub-programmes	Prof. I. Richardson, Prof. J. Sietsma, Prof. B. Thijsse, Prof. J. Dik, A. Böttger, W. Sloof
11.30 - 12.00	Reflection	
12.00 – 13.00	Lunch with PhD students	MSE: Rangan Dutta, Robbert-Jan Dikken en Willemijn Elkhuizen MTT: Etienne Duchateau, Teus van Vianen DCSC: Subramanya Nageshrao, Kim Verbert, Hans Verstraete
13.00 – 15.30	Dept. Marine and Transport Technology	Prof. G. Lodewijks, Prof. R. Huijsmans, Prof. C. van Rhee, Prof. Hans Hopman
	Lab visits	
	Four sub-programmes	Prof. G. Lodewijks, Prof. R. Huijsmans, Prof. C. van Rhee, Prof. Hans Hopman, D. Schott, S. Miedema, R. Hekkenberg, P. de Jong
15.30 – 16.00	Reflection	
16.00 – 16.45	Dept. Delft Center for Systems & Control	Prof. H. Hellendoorn, Prof. M. Verhaegen, Prof. B. De Schutter, Prof. R. Babuška
16.45 – 17.15	Lab visits	
17.15 – 18.00	Three sub-programmes	Prof. H. Hellendoorn, Prof. M. Verhaegen, Prof. B. De Schutter, Prof. R. Babuška, Tamas Keviczky, Manuel Mazo, Jan-Willem van Wingerden
18.00 – 20.00	Dinner	

Underlined names: Head of Department

Day 3: April 16, 2014. Venue: Faculty 3mE, Meeting Room MSE, Tower A, 1st floor

09.00 – 09.30	Meeting with Rector Magnificus + Dean	Prof. K.C.A. Luyben, RM + Prof. T. Baller, Dean
09.30 – 10.15	Dept. Precision and Microsystems Engineering	Prof. U. Staufer, Prof. F. van Keulen, Prof. J. Herder, Prof. R. Munnig Schmidt
10.15 – 10.45	Lab visits	
10.45 – 11.30	Three sub programmes	Prof. U. Staufer, Prof. F. van Keulen, Prof. J. Herder, Prof. R. Munnig Schmidt, Prof. G. Janssen, M. Tichem
11.30 – 12.00	Three PhD Dept. Precision and Microsystems Engineering	Giuseppe Radealli, Hugo Peters, Alikisti Gkouzou
12.00 – 13.00	Lunch	Committee
13.00 – 16.00	Preparation of draft report	Committee
16.00 – 16.15	Presentation of preliminary	All
16.15	End of the site visit - drinks	All

Underlined name: Head of Department

Appendix 4: Quantitative data

Faculty of 3mE

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	261	294	361	373	374	413
	Non-refereed articles	12	12	11	2	4	5
	Conference papers	316	420	422	378	321	291
	PhD-theses	24	30	27	33	42	39
	Books	3	5	5	7	5	2
	Book chapters	23	19	23	27	19	32
Total academic publications		639	780	849	820	765	782
Professional publications		24	33	24	29	22	32
Editorships		18	18	27	19	17	26
Patents		20	17	7	7	8	9
Prizes		3	5	9	4	5	3
Total research output		704	853	915	880	817	852

Staff	2007		2008		2009		2010		2011		2012	
Faculty of 3ME	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	111	35.6	119	39.8	116	39.3	119	40.2	120	41.4	121	41.5
Non-tenured staff	101	52.1	115	53.1	124	66.2	103	55.2	93	47.9	101	45.2
PhD-students	222	138.9	245	146.7	253	154.6	271	161.3	280	167.8	295	185.6
Total research staff	434	226.5	479	239.6	493	260.1	493	256.7	493	257.1	517	272.2

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	Fte	%	fte	%
Direct funding (1)	46.8	20	51.3	21	57.9	22	51.9	20	55.7	21	51.6	19
Research grants (2)	32.4	14	33.2	14	34.6	13	33.5	13	33.7	13	40.3	15
Contract research (3)	155.4	66	159.7	65	171.8	65	170.5	67	173.7	66	183.7	67
Total funding	234.6	100	244.2	100	264.3	100	255.9	100	263.1	100	275.6	100

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Department of Biomechanical Engineering

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	51	55	69	76	102	125
	Non-refereed articles		1	3		1	1
	Conference papers	32	38	52	56	74	59
	PhD-theses		2	2	1	4	9
	Books	1				1	
	Book chapters	6	1	3	1	3	4
Total academic publications		90	97	129	134	185	198
Professional publications		1	3	1	4	2	3
Editorships		1	1	3	1	3	1
Patents		5	7			4	3
Prizes							
Total research output		97	108	133	139	194	205

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	14	4.2	21	6.5	20	6.7	22	7.3	24	7.7	24	7.7
Non-tenured staff	23	13.5	22	11.0	25	13.	17	8.7	13	6.9	21	11.1
PhD-students	24	13.7	33	19.0	37	21.8	51	28.9	53	33.2	63	39.4
Total research staff	61	31.4	76	36.5	82	41.6	90	44.9	90	47.8	108	58.2

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	Fte	%	fte	%
Direct funding (1)	1480	54%	2389	58%	2020	44%	1982	38%	2021	36%	2192	33%
Research grants (2)	400	14%	260	6%	677	15%	1034	20%	1393	25%	1407	21%
Contract research (3)	880	32%	1439	35%	1879	41%	2241	43%	2193	39%	3051	46%
Total funding	2760	100%	4088	100%	4576	100%	5257	100%	5607	100%	6650	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Delft Center fore Systems and Control

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	25	37	39	40	41	36
	Non-refereed articles			3			1
	Conference papers	67	114	127	111	94	76
	PhD-theses	4	7	6	6	8	3
	Books	1		1	5		
	Book chapters	3	5	7	14	2	12
Total academic publications		100	163	183	175	145	128
Professional publications			1	3	1		
Editorships		5	8	12	5	5	5
Patents							2
Prizes							
Total research output		105	172	198	181	150	135

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	16	5.1	17	5.8	19	5.6	19	6.0	17	5.7	15	4.9
Non-tenured staff	20	8.4	21	9.8	26	12.9	24	12.5	21	9.6	19	7.6
PhD-students	41	26.7	45	25.6	42	25.2	52	27.8	49	27.0	47	29.6
Total research staff	77	40.1	83	41.2	87	43.7	95	46.3	87	42.4	81	42.0

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	Fte	%	fte	%
Direct funding (1)	9.4	23%	10.4	25%	13.7	31%	13.3	29%	10.1	23%	8.9	20%
Research grants (2)	9.5	23%	7.8	19%	4.9	11%	5.2	17%	5.6	13%	5.4	12%
Contract research (3)	22.2	54%	23.8	57%	25.9	58%	26.6	59%	28.0	64%	30.0	68%
Total funding	41.1	100%	42.0	100%	44.5	100%	45.1	100%	43.7	100%	44.3	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Department of Process and Energy

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	47	83	123	99	110	99
	Non-refereed articles	8	1	1	1	2	0
	Conference papers	36	52	49	43	48	27
	PhD-theses	8	6	7	10	13	8
	Books	0	2	1	0	1	0
	Book chapters	3	4	5	2	4	10
Total academic publications		102	148	186	155	178	144
Professional publications		3	4	3	4	2	4
Editorships		6	3	3	6	8	11
Patents		0	2	0	1	0	1
Prizes		1	0	2	1	1	1
Total research output		112	157	194	167	189	161

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	17	7.2	18	7.5	19	8.2	19	8.0	18	8.2	21	9.2
Non-tenured staff	19	8.9	23	9.7	29	14.8	20	11.4	26	12.3	27	12.2
PhD-students	54	37.2	58	37.4	60	39.8	56	36.3	56	37.8	58	40.2
Total research staff	90	53.3	99	54.6	108	62.8	96	55.7	100	58.3	106	61.6

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	Fte	%	fte	%
Direct funding (1)	7,2	14%	7,5	14%	8,2	13%	8,0	14%	8,2	14%	9,2	15%
Research grants (2)	8,9	17%	9,7	18%	14,8	24%	11,4	20%	12,3	21%	12,2	20%
Contract research (3)	37,2	70%	37,4	68%	39,8	63%	36,3	66%	37,8	65%	40,2	65%
Total funding	53.3	100%	**54,6**	100%	**62,8**	100%	**55,7**	100%	**58,3**	100%	**61,6**	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Department of Precision and Microsystems Engineering

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	18	34	32	42	16	30
	Non-refereed articles		2		1		
	Conference papers	49	73	55	34	14	34
	PhD-theses	2	8	3	7	3	4
	Books	1		1		1	
	Book chapters		2	3	2		1
Total academic publications		70	119	94	86	34	69
Professional publications		1	1	1			1
Editorships				3			1
Patents		13	5	7	5	3	1
Prizes			1	4			
Total research output		84	123	109	91	37	72

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	13	4.2	13	4.2	12	4.3	12	1.4	12	4.1	13	4.3
Non-tenured staff	4	2..4	8	3.9	7	4.9	7	2.6	4	2.2	6	1.7
PhD-students	33	18.9	31	18.6	26	15.9	26	15.4	29	14.9	29	19.5
Total research staff	50	25.5	52	26.7	45	25.1	45	22.1	45	21.2	48	25.5

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	fte	%	fte	%
Direct funding (1)	5.9	23%	5.4	20%	5.4	22%	5.4	24%	4.9	23%	5.3	21%
Research grants (2)	3.4	13%	3.1	12%	2.3	9%	2.3	10%	4.5	21%	8.4	33%
Contract research (3)	16.2	64%	18.2	68%	17.4	69%	14.4	66%	11.8	56%	44.8	46%
Total funding	25.5	100%	26.7	100%	25.1	100%	22.1	100%	21.2	100%	25.5	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Department of Materials Science Engineering

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	101	70	83	101	88	100
	Non-refereed articles	3	6	1	0	0	1
	Conference papers	56	74	61	60	36	32
	PhD-theses	9	3	5	5	8	8
	Books	0	1	1	0	1	1
	Book chapters	10	3	4	2	4	5
Total academic publications		179	157	155	168	137	147
Professional publications		14	18	15	11	9	17
Editorships		2	0	2	2	0	1
Patents		2	2	0	0	0	1
Prizes		1	1	1	1	1	1
Total research output		198	178	173	182	147	167

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	18	5.8	18	5.9	18	5.6	18	5.6	19	5.7	21	6
Non-tenured staff	28	15.3	31	14.8	26	14.7	27	16	25	14.1	22	9.6
PhD-students	40	27.2	47	25.9	53	33.4	48	33	53	34.1	50	32.7
Total research staff	86	48.3	96	46.6	97	53.7	93	54.6	97	53.9	93	48.3

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	fte	%	fte	%
Direct funding (1)	9.1	17%	9.6	19%	8.9	16%	8.3	15%	8.8	16%	8.9	18%
Research grants (2)	0.3	1%	0.3	0%	3.0	5%	3.6	6%	3.2	6%	4.1	8%
Contract research (3)	44.7	82%	40.3	81%	45.2	79%	45.2	79%	43.1	78%	35.9	76%
Total funding	54.1	100%	50.3	100%	57.0	100%	57.0	100%	55.1	100%	48.8	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.

Department of Marine and Transport

Output		2007	2008	2009	2010	2011	2012
Academic publications	Refereed articles	19	15	15	15	17	23
	Non-refereed articles	1	2	3		1	2
	Conference papers	76	69	78	74	55	63
	PhD-theses	1	4	4	4	6	7
	Books	0	2	1	3	1	1
	Book chapters	1	4	1	6	5	
Total academic publications		98	96	102	102	85	96
Professional publications		5	6	1	9	9	7
Editorships		4	6	4	5	1	7
Patents		0	1		1	1	1
Prizes		1	1		2	2	1
Total research output		108	110	107	119	98	112

Staff	2007		2008		2009		2010		2011		2012	
	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte	N	Fte
Tenured staff	33	9,1	329	9,9	28	8,9	29	9,2	30	10	27	9,4
Non-tenured staff	7	3,6	10	3,8	11	5,8	8	4,0	48	2,8	6	3,0
PhD-students	30	15,2	31	20,2	35	18,5	38	19,9	40	20,8	48	24,1
Total research staff	70	27,9	73	33,9	74	33,2	75	33,1	74	33,6	81	36,5

Funding	2007		2008		2009		2010		2011		2012	
	fte	%	fte	%	fte	%	fte	%	fte	%	fte	%
Direct funding (1)	3.29	61%	3.42	66%	3.62	63%	2.95	59%	3.06	61%	2.96	52%
Research grants (2)	110	2%	81	2%	80	1%	95	2%	131	3%	218	4%
Contract research (3)	1.95	37%	1.67	32%	2.01	36%	1.98	39%	1.86	37%	2.51	44%
Total funding	5.35	100%	5.17	100%	5.71	100%	5.02	100%	5.05	100%	5.68	100%

Note 1: Direct funding by the university / KNAW / NWO.
Note 2: Research grants obtained in national and international scientific competition (e.g. grants from NWO, KNAW and European Research Council.
Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European Commission and charity organizations.