

Report of the External Review Committee on the 2009 – 2016 evaluation of the Department of Biomedical Engineering, Eindhoven University of Technology

July 28, 2017

I INTRODUCTION

This report presents the results of the research assessment of the Department of Biomedical Engineering of the Eindhoven University of Technology (further to be mentioned TU/e), conducted by an external review committee. The assessment covered the quality and relevance of research conducted in the period from 2009 till 2016, the viability of the department, its research strategy, and the quality of the research training, research integrity and diversity.

The External Review Committee

To assess the research and research training conducted at the department of Biomedical Engineering (further to be mentioned 'BME'), an international external review committee was appointed by the Executive Board of TU/e. The Committee was asked to evaluate the research of the department of Biomedical Engineering according to the Dutch Standard Evaluation Protocol 2015-2021 (SEP)¹ and in relation to the department's mission as described in the self-evaluation report. This protocol aims to ensure a transparent and independent assessment process. Therefore all members of the Committee signed a statement of impartiality and confidentiality. The site visit took place on May 9th 2017 at TU/e. Additional information on the committee members and their curriculum vitae can be found in Annex 1. The Committee consisted of:

- Professor Douwe Breimer, Leiden University, The Netherlands (chairman)
- Professor Georg Duda, Julius Wolff Institute, Charité, Germany
- Professor Ursula Klingmüller, German Cancer Research Center, Heidelberg (DKFZ), Germany
- Professor Annemieke Madder, Ghent University, Belgium
- Professor Sebastien Ourselin, Centre for Medical Image Computing, University College London, United Kingdom
- Professor Carlie de Vries, Academic Medical Center, Amsterdam, The Netherlands
- Petra Uittenbogaard, MSc, Surplace Advies, The Hague, The Netherlands, appointed secretary to the review committee.

Scope of the assessment and documentation

The Dean of BME asked the Committee to provide an assessment of *"the quality, the relevance to society and the viability of the scientific research at the department, as well as the strategic targets of the department and the extent to which it is equipped to achieve these targets, by taking into account the current international trends and developments in science and society."* The assessment was carried out at the level of the department as a whole, but the Committee also made comments on the aggregate level of the three research clusters.

Working procedure of the Committee

The Committee received a well-presented, informative and comprehensive self-assessment report according to the SEP-criteria, although some relevant details on the outcome and recommendations of the previous research assessment (2002 – 2008) were missing. The committee asked for further documentation, which was obtained later.

Furthermore, the department had not taken into account the amendment that had been made to the SEP in July 2016 on 'diversity' as a third aspect that has to be considered in the qualitative

¹ The SEP protocol has been developed as an external evaluation system for all research conducted at Dutch universities, university medical centers, and NWO and Academy institutes. The Association of Universities in the Netherlands (VSNU), the Royal Netherlands Academy of Arts and Sciences (KNAW), and the Netherlands Organisation for Scientific Research (NWO) adopted the protocol.

assessment. Therefore, the committee has asked the departmental management and research staff to reflect on this aspect during the interviews.

The day before the site visit, the committee had a private kick-off meeting and discussed its first impressions based on the self-assessment report of BME.

The site visit with several interviews was very informative and took place in an open atmosphere. The committee met and spoke with a very motivated and dedicated staff at all levels of the department. The committee subsequently based its judgement on the self-evaluation report and the oral information provided in the interviews with the Dean, the group leaders representing the three research clusters, some representatives of the tenured staff (Associated and Assistant Professors), and a representation of the PhD students and the Post-Docs. Due to the tight time schedule it was not possible to conduct an extensive laboratory tour, so the Chair decided to restrict this to just one laboratory. (More information on the full program of the site visit in Annex 3.)

The department consists of three research clusters containing 11 research lines, each headed by a fulltime professor. In order to guarantee optimal attention and assessment by the committee, the chair divided the three clusters among the members of the committee in accordance with their primary expertise. This way the committee ensured that each cluster was assessed by at least two experts in those research areas.

Research Cluster	Reviewer 1	Reviewer 2
Biomechanics and Tissue Engineering	G. Duda	C. de Vries
Biomedical Imaging and Modeling (BIM)	U. Klingmüller	S. Ourselin
Chemical Biology	A. Madder	C. de Vries

The one-day visit was concluded with an oral feedback session of the findings and preliminary conclusions, attended by the Rector Magnificus of TU/e, the Dean, and the group leaders of the department.

II ASSESSMENT OF THE DEPARTMENT OF BIOMEDICAL ENGINEERING

II.1 Description of the department, its research strategy and targets

The Department of Biomedical Engineering is one of the nine departments of TU/e. The research of the department is based on three research pillars:

1. Research on **methods for (very) early diagnosis and monitoring of clinical diseases and disorders** (bio-molecular sensing, biochemical markers, advanced imaging, biosensor technology);
2. Research on **novel therapies** (drug discovery, drug delivery, tissue engineering, regenerative medicine);
3. Research on **methods for prevention and outcome prediction of interventions, clinical decision support, design and optimize tissue engineered products and to improve diagnostic techniques** (computer modeling, machine learning).

Whereas during the previous assessment in 2009, the department consisted of 8 research programs, currently BME has expanded to 11 more or less independent research groups headed by a full professor and 9 part-time professors. Typically in a group, a full professor works with an academic team of two or more staff members at the level of assistant (tenure track) or associate professor – some of them have their own independent research group - and in some cases in cooperation with a part-time professor. The groups comprise also PhD students, post-doctoral fellows and master

students (internships). Additionally, scientific and non-scientific support staff assists the teams. For the organizational structure of BME we refer to Annex 4 of this report.

Research groups operate within clusters, sharing educational tasks and using similar infrastructure, equipment and experimental methods. The clusters are:

1. *Chemical Biology*. Principal Investigators: Prof. Bert Meijer, Prof. Luc Brunsveld, Prof. Menno Prins, Prof. Maarten Merx, Prof. Jan van Hest;
2. *Biomechanics and Tissue Engineering*. Principal Investigators: Prof. Carlijn Bouten, Prof. Cees Oomens, Prof. Keita Ito, Prof. Frans van de Vosse;
3. *Biomedical Imaging & Modeling*. Principal Investigators: Prof. Peter Hilbers, Prof. Josien Pluim.

TU/e has chosen 'Health' as one of the three multi-disciplinary strategic areas, of which BME is a strong participant. The Department has been very successful in attracting more bachelor students in biomedical science and technology in recent years and is currently one of the fastest growing departments of TU/e. In 2015 the Department produced a 'Blueprint for Growth', in which a strategy for the coming decade has been defined. For the next 5 to 10 years the Department intends to augment existing groups, but also to explore new research directions, preferably between existing groups. Major targets in this strategy are:

1. Expand the Department by forming new groups and/or by strengthening existing groups (an increase in associated positions from 35 fte to 50 fte is foreseen) with a background in Biomaterials, Neuro-engineering (not yet developed and in an exploration phase), Immuno-engineering (partially existing and recently expanded with an assistant professor for immuno-engineering in the Soft Tissue Biomechanics & Engineering group) and Imaging (existing);
2. Regain strength in ultrasound imaging, centered around the PULS/e lab;
3. Research focus on MR imaging, in close collaboration with UMC Utrecht and formalized in a recent strategic alliance between Utrecht and TU/e;
4. Intensify current collaborations with national and international partners in academia, industry and the clinic;
5. Build new collaborations to facilitate and improve translation of fundamental research to the clinic, e.g. InSciTe² and RegMed XB³;
6. Professionalization of the grant application process;
7. Foster and institutionalize the collaboration with Utrecht University and UMC Utrecht by means of joint educational programs and intensified research on 'Regenerative Medicine' and 'Imaging';
8. A more flexible policy towards the career development of Associate Professors by creating the possibility to run an own independent research group.

II.2 General remarks

Self-evaluation report and site visit

The committee would first like to express its appreciation for the quality, the informative level and comprehensiveness of the self-assessment report. During the site visit, the committee very much appreciated the open dialogues and inspiring environment it experienced within the department. All discussions with staff members, PhD students and Postdocs took place in a very positive atmosphere and the committee was impressed by the dedication and enthusiasm of the PhD

² InSciTe = Chemelot Institute for Science and Technology

³ RegMed XB = Regenerative Medicine Crossing Borders

students with whom the committee interacted. This open and motivating culture in the department is something to cherish.

Organizational aspects and governance

Until the end of 2015 the number of scientific staff has been more or less constant, but since 2016 the department is growing as a consequence of the very strong increase in student numbers. The department presented its strategy and targets in the self-assessment report and presented its 'Blueprint for Growth'. The committee believes that this blueprint, of which the main topics are mentioned above, needs to be taken a step further. Further conceptualization and specification of research aims, methods to be used, funding opportunities and implementation of research results should be part of this 'second phase' research strategy. A more explicit successful societal orientation needs to be included in this strategy. (See also II.4 'Relevance to society').

Based on the recommendations from the previous assessment, all research programs are embedded within three research clusters. From discussion with staff members it became clear that this division is helpful from a managerial and educational perspective, but does not really contribute to a convincing research profile for the outside world. The committee found that the research power is clearly more at the thematic program level as presented by the Dean during the site visit (for example: medical image analysis, computational biology, regenerative medicine and tissue engineering, biomechanics, biomaterials and drug discovery). It also became clear that collaboration between such programs i.e. across research cluster borders represents a great strength of the department. The committee feels that the department should reconsider its current organizational research structure by for example keeping the focus areas of the TU/e as presented on page 35 in mind.

The department's research already covers a large spectrum of topics. The committee has taken notice of the department's intention to explore new research directions, but considers it to be wiser to strengthen the research areas that are already prospering rather than to set up a new, complex research line like neuro-immunology. On the other hand the committee strongly supports the development of immune-engineering as an essential component of regenerative medicine and tissue engineering.

Financial position

In the last eight years total funding of the department has only slightly increased from 14.738 M€ in 2009 to 15.4777 M€ in 2016. Since 2011 the percentage of research grants obtained in national and international scientific competition changed from 13% in 2009 to 8% in 2016. Research contracts for specific research projects obtained from external organizations, e.g. industry, government, European organizations and charity organizations) were similar; 32% in 2011 and 28% in 2016. In the last 10 to 15 years personal grants (Veni, Vidi, Vici and ERC grants) have become an important part of the department's funding. Substantial external research funding is essential to support the future's department's strategy and this will require further professional support. Considering the department's research orientation and strength, the committee feels that it is in principle well positioned as to be successful in obtaining major research grants from national funding organizations as well as from the EU. In addition, considering the strong potential in terms of economic and societal value of the research conducted, it is a very strong and successful strategy of BME to raise funding through public – private partnerships, like InSciTe and RegMedXB.

Just one day before the site visit, the committee was pleased to be informed by the news that Professor Carlijn Bouten was rewarded a prestigious grant in the Gravitation program funded by the Ministry of Education, Culture and Science. With this grant (18,8 M€), Bouten will be able to do top-level academic research in the field of "materials-driven regeneration medicine" for a period of ten years in collaboration with the other partners in the academic consortium; University Medical Center Utrecht, Maastricht University, and Hubrecht Institute. Professor Bert Meijer is a major participant in another Gravitation program "Functional molecular systems", illustrating the great research strength of his group.

Infrastructure

The department has built an excellent research infrastructure, which is available for all students and staff members, both tenured and non-tenured. The groups are spread out over three buildings and infrastructure is mainly organized based on the cluster division. The committee has met an open lab structure that seems to be suitable and to everyone's satisfaction.

In 2015, three years after the opening of a joint NMR facility, Philips Research withdrew from the Center for Biomedical Imaging Research (CIRE) and TU/e had to close down the whole animal facility because the facility was too expensive. At the moment BME researchers use an outhouse animal facility at the University Medical Centre in Utrecht.

The committee considers the overall research infrastructure and facilities as very adequate and state-of-the-art. There is certainly a concern with respect to the continuous need for renewing of the technological facilities and advanced instrumentation. This should be a point of discussion with the University Board being responsible for research infrastructure.

II.3 Research Quality

According to the committee research quality of the department as a whole is very good to excellent. The department has a strong position in its chosen research fields, a high impact, is internationally well recognized, evidenced by the considerable number of published papers in highly cited journals, by the above world average citation score and the number of prestigious awards and grants obtained by the scientific staff. There is no doubt that very good to excellent research is performed within all three research clusters. Several staff members have a very strong international profile, which contributes very strongly to the international visibility of the department as a whole (Meijer, Bouten, Brunsveld, Hilbers, Van Hest). The committee considers the research conducted in the **Chemical Biology cluster** overall as *world leading* in its field and of excellent quality. The same holds potentially for the research in regenerative medicine spearheaded by Professor Bouten.

The committee feels that although the number of publications in the last eight years has slightly increased from 170-refereed articles in 2009 to 219 in 2016, growth is lagging behind the research potential of the department. A concern is that the number of PhD-theses has dropped from 27 in 2015 to 18 in 2016, which is almost the same level as the number of PhD-theses in 2009 (16). The explanation given during the site visit is the strongly increased teaching load and working pressure of staff members in recent years as a consequence of the very sharp rise in undergraduate students in biomedical engineering.

Although the committee welcomes this enthusiasm among young people for this bachelor program and also the efforts to create a stimulating 'learning environment' for the next generation, including a close relationship between education and research, the teaching load of staff is a major concern. Especially for young staff members that have to build up their own track record to obtain a tenure position (Assistant Professors) or at later stages of their career are supposed to compete for large research grants, it is important to have protected research time. Writing grants for competitive funding also is a major challenge and very time consuming.

II.4 Relevance to society

The committee considers the overall subject matter of research of the department of great relevance to society. Numerous research results may sooner or later contribute to applications in the field of biomedical technology and advanced health care. This often requires structural collaboration with the medical field and in the self-evaluation report and the presentation by the Dean several examples were given in terms of part-time professorships of medical doctors working in hospitals (AMC,

Eindhoven, Utrecht, Maastricht). In addition public-private partnerships facilitate the ties with society, as well as the establishment of spin-off companies (Stentit, Life Tec, Xeltis, SyMoChem).

In the last external review the committee concluded that: “societal relevance can be increased if more collaboration with medicine is sought.” In recent years this has been pursued and partially realized, but the committee feels that this issue requires still more and in particular more structural attention.

The committee is critical about the lack of a clear and consistent policy to pursue patent applications of potentially applicable and innovative research findings. TU/e has recently fallen out of the top hundred of Europe’s most innovative universities due to the very limited number of patent applications. As a comparison, Delft University of Technology is ranked eighth in this top hundred, with 126 patents filed between 2010 and 2015 and a success rate of 84% (subsequently granted by patent offices). The committee finds it a missed opportunity that BME’s qualities are insufficiently exploited in this respect towards societal value. In the evaluation period (2009-2016) the number of patents varied from 0 to 3 a year, with one remarkable peak performance of 7 patents in 2015. In the last year of the assessment, the number of patent applications was zero.

The committee did not identify a structural and pro-active patent policy by which potential patents are ensured, except for a short referral to TU/e policy: *“It is TU/e policy to apply for a patent only if there is a distinct possibility for supporting spin-offs or having the intellectual property rights transferred to industry in due course”*. The committee feels that most of the research that is performed within the department may result in valuable intellectual property. Questions relating to patentability are often complex and usually require professional assistance. It is unclear whether researchers are stimulated to protect their inventions at an early stage and whether any support is provided by either a departmental or central-university technology transfer office. It is strongly recommended that the department, together with the University Board, develop a proactive IP-strategy and infrastructure to support valorization of the research. Furthermore (young) researchers should early in their career receive basic training on the relevance of patent applications and how to do that.

II.5 Viability

Leadership

The committee has the impression that the department enjoys strong leadership by the Dean Professor Hilbers, who is assisted by a management team. The Dean interacts frequently with the University Board as well as with the group leaders within the department. Together major internal and external developments are being discussed. Jointly they develop future strategies and identify priority areas for further investment, including new personnel. The SWOT-analysis presented in the self-assessment represents a realistic view on where the department currently stands. New staff appointments require primary attention and are in particular important because of the foreseen growth in the near future as referred to before. New and important staff appointments had already taken place in the period of the assessment thereby also rejuvenating the staff: in the Chemical Biology Cluster Prof. Brunsveld in 2008, Professor Prins in 2012 and part-time clinical Professor Scharnhorst in 2012 and Professor van Hest in 2016. In 2010 Professor Carlijn Bouten was appointed professor of Cell Matrix Interaction and after the retirement of Professor Ter Haar Romeny (program leader Imaging Group), Professor Josien Pluim was appointed as the new chair of the Medical Image Analysis group in 2014. At the same time this group was strengthened by the appointment of a part-time professor from Philips Healthcare, in order to strengthen ties with local industry. Further rejuvenation of the scientific staff was achieved by appointing 14 talented new (tenure track) assistant and associate professors, of which 4 are female and 7 from outside The Netherlands. In recent years several of them have been promoted to associate professor level. In its Growth Strategy the department shows to be very much aware of and anticipates on the retirement of 5 senior professors

between 2016 and 2025. Overall the department seems to have a clear strategy in place to pursue a good balance in age, gender and rank of the scientific staff.

Clinical interaction

The committee judges the viability of BME in principle as very healthy. More than the other two clusters the cluster of Biomechanics and Tissue Engineering has achieved a very fruitful collaboration with the clinic. The committee feels that a core future feature of the department is the strong interaction with clinical partners. As referred to before, TU/e (BME) already has strategic alliances on 1) imaging and 2) regenerative medicine with UMC Utrecht based on 15 years bottom-up collaboration, 3) monitoring with Philips Health Care and Philips Research including the surrounding hospitals and Kempenhaeghe Institute for Epilepsy, and 4) cardiovascular diseases ('Zwaartekracht subsidie' with Maastricht University).

Although considerable effort has been made to go beyond pure personal partnerships and install a structural alliance with Utrecht University and Utrecht Medical Faculty (investment in joint infrastructure and personnel), a more pronounced effort may be needed to be flexible enough to adequately react to the current needs and challenges in university medical centers, which represent major opportunities to the department.

To ensure a continuous flow of scientific interaction we strongly suggest installing a structured Clinical Science program that mirrors the graduate programs in place for engineers. Such a structured program could provide on competitive basis young clinical scientists a structured path towards an academic career and could be steered by Eindhoven towards a biomedical profile. If such program members would be provided with half a position paid by Eindhoven, for e.g. a three-year educational track, the research time for young clinical scientists could be ensured while they are still in their classical clinical educational path with remaining 50% of their medical faculty engagement. The structure should be organized such that the medical faculty departments are partnering in and the selected candidates benefit directly from being part of a highly competitive but purely science driven program. A role model may be the BIH Charité Clinical Scientist program (<https://www.bihealth.org/en/academy/bih-charite-clinician-scientist-program/>), which is actually accepted as integral part of medical specialization. If the clinical scientist would also be supplied with some small consumable money they will form a superior bridge builder in the department structure towards the partnering medical faculties.

Conclusion in assessment ratings

The SEP-protocol requires that ratings be given on overall research quality, relevance to society and viability. The committee bases these ratings on the information provided by the department in the self-assessment report as well as the further information provided during the site visit and a subsequent discussion. Of course, an external research assessment exercise is also meant to provide recommendations to further improve the quality of the research, its relevance to society and its viability towards the future. The recommendations are summarized in paragraph III of this report.

Quality	The department conducts very good, internationally recognized research.	2*
Relevance to society	The department makes a very good contribution to society.	2**
Viability	The department is excellently equipped for the future.	1***

* It should be noted that research quality is partially judged “world leading” as explained in previous paragraphs and hence would deserve a ‘1’ (SEP: “the research unit has been shown to be one of the few most influential research groups in the word in its particular field) but since the committee is supposed to judge the overall average quality of the research the final judgment is 2 (SEP: “very good internationally recognized research”).

** The department makes a very good contribution to society, but could do better in particular with respect to patent applications.

*** Viability is excellent, but it does require a further discussion on the department’s future research strategy and focus areas.

Further note that the three criteria and especially the four-point scoring system prescribed by the latest version of the SEP (Annex 6) differ from those in prior assessment protocols and are therefore not directly comparable.

II.6 Research training program

Bachelor and Master programs

The department has been very successful in attracting considerably more students in recent years, in particular in the new Bachelor program Biomedical Science and Technology. Overall there is an increased interest of students in technical studies in The Netherlands. Currently the BME department is one of the fastest growing departments of TU/e. The department offers one Bachelor program with two tracks: 1) Biomedical Engineering and 2) Biomedical Science and Technology and two Master Programs: 1) Biomedical Engineering and 2) Medical Engineering. Within their Master’s phase, students are given an opportunity to follow a specialized track on regenerative medicine.

The committee really applauds the educational culture and ambition within the department. It is clear that at all levels of the department people are aware of the importance of training good students including hands on research experience. In 2012 the department received a very positive review of the Bachelor and Masters programs by the NVAO (Accreditation Organization of the Netherlands and Flanders).

PhD training

The committee found the discussion with a selection of PhD students very inspiring. They appeared to be very motivated and pleased with the very open research climate and culture in the department, including the state-of-the-art research facilities that they can use cross-cluster wise. They also were very satisfied by the guidance and accessibility of their supervisors. PhD students also participate in the teaching of undergraduate and master students, which they generally like to do because it provides them with additional experience and skills beyond research alone.

However, the committee also observed that the teaching load for a PhD student is increasing because of the large increase in student numbers that is not paralleled by an equivalent increase of

staff and PhD students. In its self-assessment the department also acknowledges that in recent years the balance between education and research has become under pressure and out of balance. It is the expectation that as a result of the growing number of staff members, this balance will be restored soon, which the committee considers to be necessary.

PhD students confirmed that they have an individual training and development plan, which is designed at the beginning of their first year of the four-year PhD trajectory. It describes the research project, planning and supervision, but also the education program, which is a personalized program based on previous research and theoretical experience. At least once a year the progress of the PhD student is discussed and monitoring takes place to evaluate the achievements and progress of the PhD student. At the end of the first year a go/no go decision is made. Overall the committee judges the PhD training program of the department to be of high quality. A strong feature is the “career development facility” for PhD students, preparing them for a future career step also outside academia.

The committee is concerned about the relatively long duration of the PhD trajectory, i.e. the years it takes before a PhD thesis is being defended. The figures provided in Table 10 of the self-assessment report do show a considerable improvement in more recent years, but it is recommended that this should be carefully monitored.

Post-docs

Within the department there are 25 Post-docs doing both research and teaching. From the discussion with a two post-doc delegation, the committee learned that on an average every Post-doc is charged with the coaching of 2 to 3 Masters students, 5 Bachelor projects and a practical course for first year students. In general Post-docs have more time for research than the tenured staff-members. The committee got the impression that Post-docs working in the department are, like the PhD students, very pleased with their research environment including state-of-the-art facilities.

The committee has doubts however, whether there is an active guidance policy to coach Post-docs to make the next step in their career. The committee was told that some Post-docs have a development plan and a scheduled meeting with their principal investigator once a year, but the committee feels that development plans and academic career coaching are to be more formalized within the department. To prevent inbreeding, the committee emphasizes that it is also important to attract talent from elsewhere: people that bring expertise from other centers.

The committee met some female scientists who were very enthusiastic about working in BME, but the committee got the impression that there is no active policy on promoting women towards higher scientific positions. The committee considers this to require urgent management attention.

II.7 Research integrity

According to the committee, the department adheres to the rules and regulations of scientific integrity. The department has a pro-active approach on research integrity in accordance with the policy of the TU/e. Professor Cees Oomens is the departmental representative in a TU/e-wide Committee for Academic Integrity. No major issues have arisen over the past assessment period and PhD students seemed to be well aware of the important aspects of academic integrity and the TU/e Code of Conduct. All academic staff and master students have to sign a declaration that they are aware of this code and do subscribe to the central values of TU/e regarding research integrity.

This all being formally in order, the committee feels that issues of scientific integrity and good academic research conduct require continuous attention and discussion (considering for example publication pressure, competitive grant application, etc.)

II.8 Diversity

Diversity is considered to be a key factor for the future development of excellent universities. To promote all talent a structured mentoring program is essential. It is important to identify in particular female talent early and ensure sufficient encouragement to pursue a career in science. The transition from doctoral student to post-doctoral fellow is critical. Therefore a structured mentoring program that provides courses e.g. on presentation and grant writing skills, opportunities for networking and individualized mentoring is highly beneficial. These activities should be a mandatory part of a graduate school program and should be also open to postdoctoral fellows. Additionally, it is important to promote and support female role models since their example encourages others to take up the same path and provides a source for advice. Finally, opportunities for dual careers should be actively provided and advice should be continuously offered.

III RECOMMENDATIONS

Below the committee summarizes some important recommendations in random order.

1. Strategy

- a. Further conceptualization of research aims, methods, funding and implementation of research results should be part of a 'second phase' research strategy of the department, also taking the overall strategy of TU/e in the area of 'Health' into account.
- b. Intensifying structural collaboration with medical departments and biology should be given high priority.
- c. Strengthen the research areas that are already prospering rather than to set up a new, complex research line (e.g. Neuro-immunology, which is a very competitive research area.) On the other hand the committee strongly supports the development of immune-engineering as an essential component of regenerative medicine and tissue engineering.
- d. Considering the strong potential in terms of economic and societal value of the research conducted, a more active patent policy should be pursued and professionally supported. It should also be possible to obtain more funding through public – private partnerships, like InSciTe and RegMedXB.

2. Organization and infrastructure

- a. The department should reconsider its current organizational research structure by, for example, putting the research themes more at the front.
- b. The continuous need for renewing of the technological facilities and advanced instrumentation should be a point of discussion with the University Board being responsible for research infrastructure.
- c. The teaching load of staff members requires urgent department's attention. It is important to have protected research time, especially for young staff members that have to build up an own track record or have to compete for large research grants.
- d. Issues of scientific integrity and good academic research, although formally well organized, require continuous attention and discussion (e.g. publication pressure, competitive grant application etc.)

3. Training and education

- a. To restore the balance between education and research, the committee considers the department's strategy to increase the numbers of staff members as a necessary measure.
- b. Despite an improvement of the duration of the BME PhD trajectories in recent years, the committee recommends that this should be carefully monitored.
- c. Individual career development plans and academic career coaching are to be more formalized within the department.

4. Diversity

- a. To prevent inbreeding, it is of great importance that talent and expertise from elsewhere is being attracted.
- b. It is of urgent management attention that an active policy on promoting women towards higher scientific positions is being developed.
- c. Female role models should be supported, since their example will encourage others to take up the same path in science.
- d. Opportunities for dual careers should be facilitated and advice should be continuously offered.

5. Clinical interaction

- a. Stronger structural interaction and collaboration with clinical medicine should be pursued (1b).
- b. To further facilitate and ensure a continuous flow of scientific interaction, installing a structured Clinical Science program that mirrors the graduate program for engineers is suggested

6. Societal relevance

- a. The department should exhibit greater awareness of its great potential societal relevance and impact.
- b. It is strongly recommended that the department, together with the University Board, develop a proactive IP-strategy and infrastructure to support valorization of the research (1d).

IV ANNEXES

Annex 1 Short CV Members Assessment Committee

Professor Douwe Breimer (Chair)

Douwe Breimer is a Dutch pharmacologist and was both Rector Magnificus and President of the Executive Board of Leiden University, The Netherlands. He studied pharmacology at the University of Groningen and obtained his PhD from the Catholic University of Nijmegen, both in the Netherlands. In 1975, he was appointed professor of pharmacology at Leiden University. His scientific research focused on pharmacokinetics, pharmacodynamics and drug metabolism. During his scientific career, he co-authored over 500 scientific papers and supervised more than 50 PhD students. Douwe holds honorary doctorates from Ghent University, Uppsala University, Semmelweis University (Budapest), the University of Navarra (Pamplona), Hoshi University (Tokyo), the University of London and the Université de Montréal. In addition, he was Vice-President of the general board of The Netherlands Organization for Scientific Research (NWO) from 1996 to 2001. On a regular basis he is chairman of external review committees.

Professor Georg Duda

Georg Duda is Vice-Director of the Berlin-Brandenburg Center for Regenerative Therapies (BCRT) and the Director of the Julius Wolff Institute for Biomechanics and Musculoskeletal Regeneration at Charité – Universitätsmedizin Berlin in Germany. Dr. Duda received a degree in Precision Engineering and Biomedical Engineering from the Technical University in Berlin. After working as a Special Project Associate in the Biomechanics Lab at the Mayo Clinic in 1991 and 1992, he became a Ph.D. student in the Biomechanics Department of the Technical University in Hamburg-Harburg where he received his Doctorate in 1996. He was also engaged as a Postdoctoral Fellow in the Section Trauma Research and Biomechanics at the University Ulm. In 1997 he became Head of the Research Department at the Center for Musculoskeletal Surgery (CMSC) at the Charité. In 2001, he habilitated and accepted a call to a Professorship in “Biomechanics and biology of bone healing”. Since 2008 he is the Director of the Julius Wolff Institute and W3-Professor for Biomechanics and Musculoskeletal Regeneration. He is interested in the tension between the fields of biology and mechanics. He is involved in investigating the interaction between bone and muscles as well as the biomechanical influences and its impacts in both the intact and injured musculoskeletal system (e.g. loading of joints and bones). Particularly, he focuses on the interaction between the physical and mechanical conditions, and the biological regeneration of the musculoskeletal system. He is also involved in research on regenerative medicine. With his work he aims to understand the body's own processes, and where necessary, to stimulate them, so as to reproduce natural regeneration of the musculoskeletal system.

Professor Ursula Klingmüller

Ursula Klingmüller is educated as a Molecular Biologist. After having received her diploma in molecular biology, cell biology and virology at Ruprecht-Karls-University in Heidelberg, she became a PhD student in the group of Prof. Dr. H. Schaller at the ‘Center for Molecular Biology Heidelberg (ZMBH)’. After her PhD she went abroad to become Senior Scientist at Harvard Medical School (Boston, USA) in the group of Prof. Dr. Lewis C. Cantley (1992-1993) and in the Whitehead Institute for Biomedical Research (Cambridge, USA) in the group of Prof. Dr. Harvey F. Lodish (1993-1996). From 1996-2003 she was group Leader of an independent Junior-Group (Hans-Spemann-Laboratory) Max-Planck-Institute for Immunology, Freiburg. In 2003 she became Head of the tenure-track Theodor Boveri Group ‘Systems Biology of Signal Transduction’ in the German Cancer Research Center (DKFZ) in Heidelberg. From 2008 she is Head of this division.

Professor Annemieke Madder

Annemieke Madder is Head of the Department of Organic Chemistry at Ghent University.

Professor Seb Ourselin

Seb Ourselin is Director of the newly founded Wellcome / EPSRC Centre for Surgical and Interventional Sciences in London. He is currently Vice-Dean (Health) at the Faculty of Engineering Sciences, Director of the Institute of Healthcare Engineering and of the EPSRC Centre for Doctoral Training in Medical Imaging, Head of the Translational Imaging Group within the Centre for Medical Image Computing (CMIC) and Head of Image Analysis at the Dementia Research Centre (DRC). He has published over 400 articles and raised over £40M as Principal Investigator. He is an associate editor for IEEE Transactions on Medical Imaging, Journal of Medical Imaging, Nature Scientific Reports, and Medical Image Analysis. He has been active in conference organization (12 international conferences as General or Program Chair) and professional societies (APRS, MICCAI). He was elected Fellow of the MICCAI Society in 2016. Before joining UCL, he founded and led the CSIRO BioMedIA Lab, Australia. He led the imaging research program of the AIBL study and of a successfully commercialized colonoscopy simulator. He leads the translational imaging research program between CMIC and the National Hospital for Neurology and Neurosurgery.

Together with Professor Nick Fox he has established a new imaging unit to deliver engineering solutions for clinical trials. With Prof. John Duncan, he leads the development of an image-guided neurosurgery platform, deployed within the iMRI environment for temporal lobe epilepsy. This work built the foundation for expanding into neurosurgical planning (HICF). He is also leading the development of the open-source NifTK platform (>20,000 downloads). Most of these activities are underpinning GIFT-Surg's technological foundations, an Innovative Engineering for Health grant funded by the Wellcome Trust and EPSRC. In 2015, he founded a UCL spin-out company aiming at delivering automatic quantitative imaging through PACS-embedded clinical reports (Brainminer Limited). The company has raised so far over £1M through SBRI by leveraging a uniquely patented technology enabling robust brain parcellation.

Professor Carlie de Vries

Carlie de Vries is Professor of Medical Cell Biochemistry at the Faculty of Medicine of the University of Amsterdam (AMC-UvA) and heading the Vascular Cell Biology group. Carlie uses her research to gain detailed insight into the molecular processes involved in the initiation and progression of atherosclerosis. Atherosclerosis is a condition affecting the arterial vessel wall that can ultimately lead to obstruction of normal blood flow resulting in a heart attack or stroke. Through her molecular biological research, De Vries is able to identify genes that have a key regulatory function in atherosclerosis. The resulting insights are used towards early patient diagnosis and to develop innovative treatment strategies. De Vries works in close collaboration with cardiologists at the AMC, thus ensuring maximum integration with clinical practice and the translation of new fundamental knowledge into practical applications. De Vries received a research subsidy totaling five million euros from Biomedical Materials to conduct basic scientific vascular research and to collaborate with three small companies and TU Delft on the development of a safer stent (a small tubular device used to keep an artery open after angioplasty).

Petra Uittenbogaard (Secretary)

In 2007 Petra Uittenbogaard (1974) received a Master's degree in Health Sciences at Maastricht University. After having worked as a quality manager in the St. Antonius Hospital in Nieuwegein from 1997 till 2000, Petra moved back to Maastricht and worked as a policy advisor and organizational consultant in a large care organization for elderly care in Heerlen, and as a strategic consultant in various health care organizations. In 2002 she was contracted as an advisor to the Executive Board of the academic hospital in Maastricht (azM). Her project portfolio mainly consisted of projects in the field of strategic alliances, academic cooperation with other hospitals and care suppliers in the Maastricht region, organizational development, and projects shared by both hospital and the medical faculty on translational medicine and the development of a university center in Maastricht. Petra has ample experience in managing the process of (inter)national advisory boards and review committees. In 2010 and 2016 she was secretary to the External Review Committee on respectively the assessment of CAPHRI School for Public health and Primary Care and MHeNs School for Mental

Health and Neuroscience in Maastricht. November 2008 she was secretary to the International Scientific Advisory Board of CARIM (Cardiovascular Research Institute) at Maastricht University. From July 2011 she uses her knowledge and experience within her own company.

Annex 2 – Mission letter of the Dean

Department Biomedical Engineering

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GEMINI-zuid
www.bmt.tue.nl

**Review Committee for the
Research Assessment Biomedical Engineering TU/e**

Date
March 29th, 2017

Subject
Research Assessment Biomedical
Engineering TU/e (BME-TU/e)
2009 – 2015

Department Board

Prof.dr. P.A.J. Hilbers
Decaan

Prof.dr.ir. L. Brunsveld
Vice decaan

Prof.dr.ir. C.W.J.
Oomens
Vice decaan

Mr. J.M.R. Debey
Directeur
bedrijfsvoering

Contact
p.a.j. hilbers
@tue.nl

Dear members of the Review Committee for the research assessment Biomedical Engineering TU/e (BME-TU/e) 2009 – 2016,

We are honoured that you are willing to participate in the review committee to assess the research of the department of Biomedical Engineering.

You are being asked to assess *the quality, the relevance to society* and the *viability* of the scientific research at the department as well as the strategic targets of the department and the extent to which it is equipped to achieve these targets, on the basis of the Standard Evaluation Protocol (SEP). You should do so by taking into account the current international trends and developments in science and society.

The assessment will be carried out at the aggregate level of the department as a whole on the basis of a written self-evaluation and a site visit but comments on smaller aggregate levels are very much appreciated.
This self-evaluation report you will find enclosed.

You are asked to judge with a specific forward look not only the performance of the research of the department, but also its leadership, strategy and policy, and research organization. Have the main themes of research been well chosen in the previous seven years? Is the research unit well equipped to compete with world-class research groups in the future?

Discussions about the future requires knowledge of the past. Therefore, the evaluation will be a combination of retrospection and prospective analysis. However, the emphasis of the assessment should be on the *prospective analysis*.

We are looking forward to a fine collaboration and pleasant site visit and a successful evaluation.

Yours sincerely,



Prof.dr. P.A.J. Hilbers
Dean

Enclosure: Self-evaluation report

Program Research Assessment May 9th, 2017

Location: Eindhoven University of Technology, department of Biomedical Engineering, Building GEMINI-zuid, room 1.03

08.30 h. Welcome

08.45 h. Introduction by the dean of the department BME,
Prof.dr. P.A.J. Hilbers 'Reflection on the strategy'

09.45 h. Break

Meeting with the research group leaders

10.00 h. Biomechanics and Tissue Engineering,

- *Cell-matrix Interaction*, Prof.dr. Carlijn Bouten
- *Biomechanics of Soft Tissue*, Prof.dr.ir. Cees Oomens
- *Cardiovascular Biomechanics*, Prof.dr.ir. Frans van de Vosse
- *Orthopaedic Biomechanics*, Prof.dr. Keita Ito

10.45 h. Biomedical Imaging & Modelling (BIM);

- *Medical Image Analysis*, Prof.dr. Josien Pluim
- *Computational Biology*, Prof.dr. Peter Hilbers

11.15 h. Chemical Biology (CB);

- *Chemical Biology*, Prof.dr.ir. Luc Brunsveld
- *Biomedical Chemistry*, Prof.dr. Bert Meijer
- *Molecular Biosensing for Medical Diagnostics*, Prof.dr.ir. Menno Prins
- *Bio-Organic Chemistry*, Prof.dr.ir. Jan van Hest
- *Protein Engineering*, Prof.dr. Maarten Merkx

12.00 h. First reflections and Lunch

13.15 h. Visit PULS/e; Photoacoustics & Ultrasound Laboratory Eindhoven
Gemini-Zuid 4.08

14.00 h. Meeting with Associated and Assistant Professors

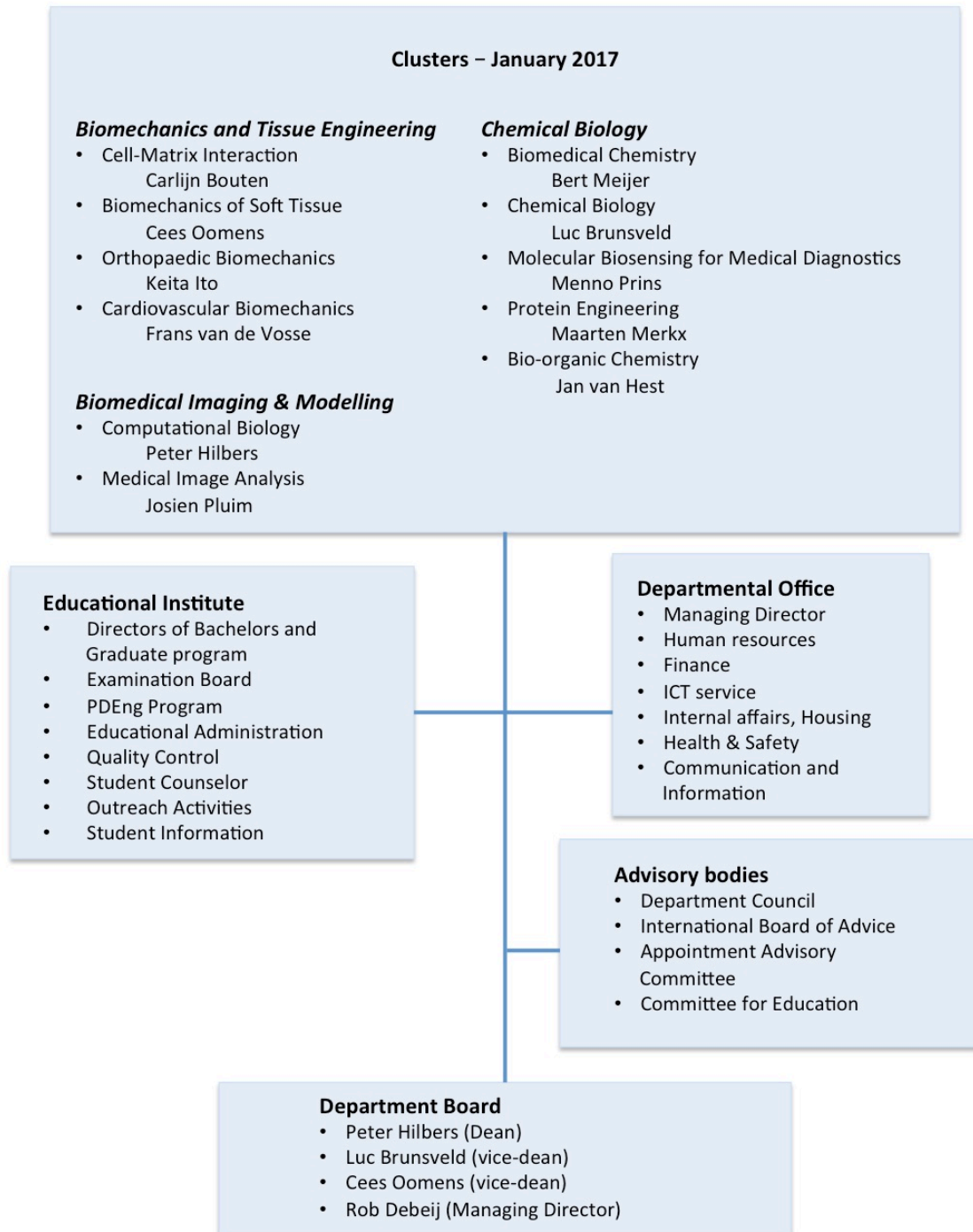
14.30 h. Meeting with PhDs

15.00 h. Meeting with Postdocs

15.15 h. Review by the committee

16.30 h. Feedback by the committee

Annex 4 Organogram Department of Biomedical Engineering at TU/e



Annex 5 Composition (A) and financing (B)

Table 5A Composition: research staff at Dept. of BME

Research staff in fte ¹	2009	2010	2011	2012	2013	2014	2015	2016
Scientific staff ²	31.4	32.4	30.4	30.4	31.0	31.5	31.3	35.3
Postdocs	31.4	33.3	30.4	32.8	26.0	24.0	28.75	25.6
PhD students ³	P=103.8 N=18.2	P=111.2 N=12.2	P=103.8 N=9,1	P=93,2 N=22,1	P=94.2 N=25,8	P=90.7 N=26.0	P=85.0 N=22.0	P=83.0 N=21.0
Total research staff	184.8	189.1	173,7	178.5	177.0	172.2	167.05	164.9

1. Total time of appointment in fte (fulltime equivalents); available for research, education, and organizational tasks.
2. Full, associate and assistant professors; tenured and non-tenured staff.
3. PhD students, including both fully employed by the Department (P) and externally or internally funded but not employed by the Department (N).

Table 5B Financing and facilities: funding of the Department of BME

Table 5B presents information concerning the total funding and expenditures of the department, including the funding and costs for non-research staff, e.g. educational and supporting staff. The department depends financially on 1) direct university funding, as well as on acquisition of 2) research grants, 3) contract research and 4) other funds.

	2009		2010		2011		2012		2013		2014		2015		2016	
<i>Funding:</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>
Direct funding ¹	9.735	66	10.683	67	10.955	60	9.485	61	9.026	62	9.305	63	9.870	63	9.933	64
Research grants ²	1.943	13	1.762	11	1.563	9	960	6	1.168	8	932	6	1.164	7	1.204	8
Contract research ³	3.060	21	3.604	22	5.815	32	5.165	33	4.342	30	4.632	31	4.612	29	4.339	28
Total funding	14.738	100	16.049	100	18.332	100	15.610	100	14.535	100	14.869	100	15.646	100	15.477	100
<i>Expenditure:</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>	<i>M€</i>	<i>%</i>
Personnel costs	11.156	75	11.446	71	11.463	70	10.994	70	10.906	74	10.860	73	11.405	72	12.179	77
Other costs	3.734	25	4.725	29	5.018	30	4.603	30	3.743	26	3.956	27	4.477	28	3.670	23
Total expenditure	14.891	100	16.171	100	16.481	100	15.597	100	14.649	100	14.816	100	15.883	100	15.849	100

1. Direct university funding (lump-sum budget, shown as millions of euros).
2. Research grants obtained in national and international scientific competition (e.g., grants from NWO and KNAW).
3. Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European organizations and charity organizations.

Direct university funding provides for the salaries of the tenured research staff, educational and supporting staff, some small expenditures and the Department exploitation costs of housing.

External grants provide for the running costs of the research projects, including PhD students and postdoc salaries, bench fees, consumables and capital investment in equipment. A typical grant is for

a research period of 3 – 5 years and includes the salary, costs for consumables, international travel and some investment money for 2 – 5 PhD students and postdocs, depending on the source of the grant. Part of these grants originates from national funding based on project proposals in open competition. This is either government funding (NWO, STW) or funding from foundations like “The Heart Foundation” and “Dutch Arthritis Foundation”.

Other grants are financed through public private partnership agencies (BMM, CTMM, InSciTe), industrial contracts and European programs (Horizon 2020). In the last 10 to 15 years personal grants (Veni, Vidi, Vici and the ERC grants) have become an important part of the funding (Appendix 4, table A). For the total funding of the Department see Table 2. Finally, the Chemical Biology cluster is supported by a 10 years Gravitation Program in collaboration with the organic chemistry groups of Nijmegen and Groningen.

In the Department budget allocation scheme a portion of the direct annual funding by the university is earmarked for educational support and organization, overhead, and for discretionary funds for new initiatives. The majority of the budget is allocated to the groups according to permanent staff size.

Annex 6 Explanation of the categories utilized

Meaning of categories in SEP 2015-2021

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

Colophon

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Edited by

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Petra Uittenbogaard, MSc, secretary to the external review committee

The Hague, June 2017