QANU Research Review
Department of Biomedical Engineering at Eindhoven University of Technology

November 2010

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Foreword

This report follows the Standard Evaluation Protocol 2003-2009 for Public Research Organisations (SEP) that was developed by VSNU, KNAW and NWO. The purpose of this report is to present a reliable picture of the research activities submitted for this review and to give feedback on the research management and quality assurance.

The review Committee was supported by QANU (Quality Assurance Netherlands Universities). QANU aims to ensure compliance with the SEP in all aspects and to produce independent assessment reports with peer review Committees of international experts in the academic fields involved.

QANU wishes to thank the chairperson and members of the review Committee for their participation in this assessment and for the dedication with which they carried out this task. We also thank the staff of the units under review for their carefully prepared documentation and for their co-operation during the assessment.

Quality Assurance Netherlands Universities

Mr. Chris J. Peels
Director

Dr. Jan G.F. Veldhuis
Chairman of the Board

Preface by the chairman

The External Review Committee had the task to evaluate seven (of eight) research programmes and their organizational embedding in the Department of Biomedical Engineering, Eindhoven University of Technology. The review covers the research in the period 2003-2008.

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

The Committee appreciated the thorough self-assessment that was provided by the Department, the intense but pleasant visit to the Department and the openness of the interviews and discussions with group leaders, Staff Members, Postdocs, and PhD and MSc students.

The evaluation is presented in numbers, scores, and in text. We strongly believe that the scores are only one element in the assessment and they should never be used as the only 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 must be taken into account. 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 the Technical University Eindhoven. Several remarks are intended as suggestions for improvement of the Department.

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

Prof. dr. Nico Westerhof
Chairman of the Review Committee

1. The review Committee and the review procedures

Scope of the assessment
The review Committee was asked to perform an assessment of the research of the Department of Biomedical Engineering (BME) at Eindhoven University of Technology. The review will cover seven research programmes and covers the research in the period of 2003 – 2008.

In accordance with the Standard Evaluation Protocol 2003-2009 for Public Research Organisations (SEP), the Committee's tasks were to assess the quality of institutes and research programmes on the basis of the information provided by the institutes and through interviews with the management and 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. N. (Nico) Westerhof, chairman
- Prof. dr. P.M.A. (Peter) Sloot
- Prof. dr. M. (Markus) Rudin
- Prof. dr. F.C.P. (Frank) Yin

A short curriculum vitae of each of the Committee members is included in Appendix A.

Dr. Meg Van Bogaert of the Bureau of QANU (Quality Assurance Netherlands Universities) was appointed secretary to the Committee.

Independence
All members of the Committee signed a statement of independence to safeguard that they would assess the quality of the institutes and research programmes in an unbiased and independent way. Any existing personal or professional relationships between Committee members and institutes under review were reported and discussed. 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 parts:

1. Self-evaluation reports of the department under review, including all the information required by the Standard Evaluation Protocol (SEP), with appendices;
2. Copies of three key publications per research programme.

Remarks about the data provided
The information provided was well presented in a strictly systematic way, which made reading easy. The appendices gave sufficient detail. A CD was made available with all information, including the key publications in full text.

Procedures followed by the Committee
The Committee proceeded according to the SEP. Prior to the first Committee meeting; each research programme was assigned to a first and a second reviewer in the Committee.

A preliminary assessment was independently formulated on the basis of the key publications and the self-assessment report. Preceding the interviews, the Committee was briefed by QANU about the research assessment according to SEP. The Committee discussed the preliminary assessments. For each research programme a number of comments and questions were decided upon. The Committee also agreed upon procedural matters and aspects of the assessment. The final assessment is based on the documentation provided by the department, the key publications and the interviews with the management and with the leaders of the programmes. The site visit took place on April 8 and 9 2010 (see the schedule in Appendix B) at Eindhoven University of Technology. After the interviews, the Committee discussed the scores and comments. The texts for the report were finalised through email exchanges. The final draft version was presented to the department for factual corrections and comments. The final report was presented to the Board of the University and was printed after its formal acceptance.

The Committee used the rating system of the SEP; the meaning of the scores is described in Appendix B.

2 General remarks

Department level
The Committee received a good and informative self-assessment report, pertaining to the period 2002 - 2008. This made the evaluation easy and straightforward. The Department of Biomedical Engineering consists of eight research programmes of which seven were evaluated (the 8th group started only in 2007). The site visit was informative and there was an open atmosphere. Our judgment is based on the self-assessment report, and the site visit, where the oral information provided by the Dean, the discussions with the seven leaders of the research groups, the information given by the staff, and by students at master and PhD level, was all very useful. A laboratory tour was conducted, where equipment, techniques, and organization were demonstrated.

A first and most important remark is that the research quality of the Department of Biomedical Engineering as a whole is very good. The Department's scientific output in numbers of papers is good and the citation analysis shows that citation scores are 70% above world average in the field. Excluding papers based on collaboration, i.e. the Departments 'own' papers, the citations are even at the 2.7 level. The number of PhD theses is sufficient. External funding is overall very good; many Veni, Vidi and Vici grantees are present.

The leadership is good; and communication lines are short at all levels. Groups are not too large and about equal in size. The Committee is especially impressed by the good collaboration between groups/group leaders. The good collaboration is emphasized by the shared facilities and laboratories. This system appears to work very well on an informal basis, it is cost efficient, and helps to increase collaboration between researchers and support staff. The facilities are adequate and modern. Students, both at the PhD and MS level, are in direct contact with the professors. Based on the discussions with group leaders and students there is great enthusiasm for teaching and the quality of the teaching appears very good.

Three programs are qualified as 'excellent' quality, and two are in-between 'very good and excellent'. The relevance of the work is good, both in terms of science and societal, but the societal relevance can be increased if more collaboration with medicine is sought. Prospects and viability can also be improved if the below mentioned advise is considered seriously.

Nonetheless, the Department faces a number of problems. The Department is a Department of Biomedical Engineering. Unfortunately both a biology department and an academic hospital are lacking at the TU/e. This means that these fields of expertise need to be sought at other universities. There is collaboration with biology and medicine, but the Committee suggests making considerably more efforts to intensify the collaboration medical departments and biology.

The Department consists of 8 research programmes and it tried to show their coherence in three themes. This latter organization in themes is rather artificial and does not seem to play a role in terms of organization and steering. The names of the themes are not well chosen as well. If the Department wishes to use the themes they should be defined better and implemented as a steering mechanism.

Another concern is the tendency of 'inbreeding'. Most PhD-students and certainly Postdocs and staff are recruited from (former) students of the Department. The Committee advises to always use competitive international searches for candidates at all levels. The relations with industry should be expanded.

We place a word of caution about the scores: they are a tool, not a goal in themselves. The Committee adhered to this practice in the Netherlands, but realizes its limitations.

Programme level

Three programmes were top-scorers in their fields and are considered of excellent quality. These are Macro-Organic Chemistry, Biomedical Image Analysis, and Soft Tissue Biomechanics & Engineering. Macro-organic Chemistry is considered as top in all respects of the evaluation. This programme is directly followed by the programmes Biomedical Image Analysis, and Soft Tissue Biomechanics & Engineering. All three programmes are of high quality, relevance and have viability. Biomedical NMR and Bone & Orthopaedic Biomechanics are very good to excellent programmes. The NMR is trying to expand through contacts with industry since apparatus are expensive; this approach is encouraging. Bone & Orthopaedic Biomechanics had a change in programme leader, but the Committee is impressed by this new leader and by the approach he is taking. The programme Biomodeling & Bioinformatics scores good. It is suggested that this programme should focus on Biomodeling. This group could then also support modeling approaches in the other programmes. The programme Cardiovascular Biomechanics is small in terms of staff (e.g., no associate professor). The group has not only a low total scientific output but also a low number of total citations and low number of highly-cited publications. Consequently, the H-indexes of the tenured faculty, including the programme leader, are all below what one would expect of a world-class group. The research is funded by external grants, through collaboration with clinical groups, but the group received no personal awards. Since valvular function is dependent on cardiac and arterial function it should be considered to make this programme part of Soft Tissue Biomechanics & Engineering.

3. Assessment at Department level

3.1. Introduction

The Department of Biomedical Engineering (BME) is one of the nine departments of Eindhoven University of Technology (TU/e) and was established in 1999. Before the start of a new programme in Biomedical Engineering in 1997 the department was effectively a virtual one, the educational programme being distributed over several departments of the TU/e and Maastricht University.

The development of the research programmes reflects the process of transition from an educational institute into a true department with full-fledged research that is intimately and mutually connected to educational programmes. Three professor groups were recruited from other TU/e departments to found the department in 1999. The three groups started research themes organized in divisions (Biomechanics & Tissue Engineering, Biomedical Imaging & Modelling, and Molecular Bioengineering & Molecular Imaging). These divisions were strengthened by four new professors to give the divisions a critical mass. In recent years in one programme a new professor was appointed as head, and a further appointment was made to start a new group. All seven research groups evaluated are conceptually and methodologically oriented, and perform both fundamental and application oriented research. The eighth group was not evaluated since it was formed only at the end of the evaluation period (2008).

Since modern biomedical engineering research is strongly interdisciplinary, groups need to communicate directly. Laboratories and facilities, including technical personnel, are shared to enhance cooperation between groups. The interdisciplinary nature of the research is reflected by the organization of research into three central themes. Research projects are frequently performed across not only disciplinary, but also departmental boundaries. The central themes are:

- Regenerative Medicine
- Molecular Imaging
- Systems Biology

In 2003 the Institute of Biomedical Engineering Sciences & Technology/Eindhoven (BEST/e) was founded. The institute combines the efforts of several departments in research, and graduate and postgraduate education in the field of biomedical engineering.

In recent years, several large programmes, such as the Centre for Translational Molecular Medicine and the Biomedical Materials programme have started. In these programmes companies, university hospitals and academia collaborate dedicated to regenerative medicine, medical imaging, diagnosis and therapy. Strong relations between university and industrial laboratories have been established, e.g. by the appointment of several part-time professors from industry. The infrastructure and above mentioned developments have a significant impact on the research of the department, as well in the educational programme.

3.2. Leadership

The Department Board is appointed by the Executive Board of the university, and consists of a Dean, a Vice-Dean, a Vice-Dean from Maastricht University, and the Managing Director. The Director of Education and a student representative attend the weekly board meetings as advisors. The Dean is ultimately accountable for the entire management, in

which the Managing Director covers all matters concerning personnel and organization, financial administration, services and housing. Communication between the Department Board and the research groups is direct, without intermediate levels. In addition, the research groups share facilities and supporting staff, stimulating mutual communication.

The department has a number of advisory bodies that play a role in decision-making processes.

A monthly meeting of the Department Board and the group leaders is a major communication channel. Each group leader communicates with his own group. General policy developments are communicated during plenary sessions of the department. In addition there are the following annual meetings:

- Between the Dean, Managing Director and each group leader to discuss staff, including development and career opportunities;
- Between the Dean and each group leader to discuss in detail the functioning of the research group, including its relation to other groups in the department;
- A 'Research Day' in which all scientific staff participates. On this day, staff members present and discuss the challenges in their field, either orally or via posters.

3.3. Mission & Goals

Taking into consideration the history and industrial context as described in paragraph 3.1.1, the mission of the department is summarized as follows:

- To be an internationally recognized research institute offering (post-)graduate programmes to educate scientists and engineers who master a cross-disciplinary approach for advanced biomedical research and development
- To advance and apply engineering principles and tools
  - to unravel the pathophysiology of diseases, and
  - to enhance diagnostics, intervention and treatment of diseases by combining natural science and engineering

3.4. Strategy & Policy

The research in the Biomedical Engineering department is organized within the BEST/e research institute. This assessment involves the research performed in the BME department only. The BME department is organized in eight groups:

1. Chemical Biology
2. Macro-Organic Chemistry
3. Biomedical NMR
4. Soft Tissue Biomechanics & Engineering
5. Bone and Orthopaedic Biomechanics
6. Cardiovascular Biomechanics
7. Biomedical Image Analysis
8. Biomodeling and Bioinformatics

The research of groups 1, 2 and 3 is based on a molecular approach to biomedical engineering problems. In the research of groups 4, 5 and 6, principles from fluid and solid mechanics and biology are applied to a variety of biomedical problems and devices. In the last two groups, 7 and 8, research is characterized by the application of methods and

techniques from mathematics, computer science, physics, electrical engineering and medicine to the imaging and modelling of biomedical systems.

Interdisciplinary research between the groups is realized in three thematic programmes:

- Regenerative Medicine
  Research in this theme applies tissue engineering, stem cell therapy, medical devices and other techniques to repair damaged or diseased tissues and organs.
- Molecular Imaging
  In this theme the disciplines molecular biology and *in vivo* imaging are united with the aim of designing, fabricating and using specific biomarkers.
- Systems Biology
  This theme aims to enhance the shift from 'describing' life's processes to 'understanding' them and 'capturing' them in validated predictive models, and even 'managing' or 'controlling' them. The scope of this theme covers all levels from molecules to organs and humans.

Assessment of the Committee on Leadership, Mission and Goals and Strategy & Policy

The leadership is strong within the department. Collaboration between groups is good and external funding for the department as a whole, is considerable. However, more contact with the clinic is required, in order to receive valuable feedback. The Committee acknowledges that translation between clinic and fundamental research is very difficult, but is of great importance. Although individual attempts by group leaders have been made, success is still limited. This limited collaboration probably stems from two major causes: there is no University Medical Centre at Eindhoven and there is a 'distance in thought and approach'. It may help to appoint medical doctors as part-time professors that can form the bridges needed, and to direct research more to pathophysiological mechanisms. Also the collaboration with biologists should be intensified.

The vision on planning for the future is not clear. It is too much left to the individual groups. The mission of the department, as presently stated is not clearly seen in the research, and should be more focused.

All groups use modelling approaches, next to the Biomodeling and Informatics group, which is too small to provide support to the modelling efforts of the other groups. Coordination should be improved. The department should pay more attention to internationalization: attract more international staff and students (especially PhD-students).

3.5. Resources

Typically, a research group consists of a full professor, one associate professor, two to three assistant professors, a part-time professor, several technicians, a secretary and temporary scientific personnel (PhD students and postdocs). Table 3.1. provides an overview of the composition of the scientific and supporting staff of the department as a whole. Table 3.2. provides an overview of the staff for the individual research programmes.

The department management indicated that a nominal 0.4 fte is spent on research, but differences between the research programmes exist. In some programmes, time spent on research can be up to 0.7 fte, in other programmes down to 0.2 fte. The exact number is influenced by the time spent on education.

	2003	2004	2005	2006	2007	2008	average
Tenured staff	9.7	10.0	10.1	10.5	10.2	10.0	10.1
Non-tenured staff	2.1	2.0	2.1	2.4	3.5	3.7	2.6
Post-doctoral fellows	4.2	6.2	8.4	12.0	11.4	13.3	9.3
PhD students	43.5	50.5	52.8	55.3	59.7	63.5	54.2
Total research staff	**59.5**	**68.7**	**73.4**	**80.2**	**84.8**	**90.5**	**76.2**

Table 3.1: Staff at department level (in research fte; 0.4 (assistant/associate) professors, 0.1 part-time professors, 0.8 postdoc and PhD)

	2003	2004	2005	2006	2007	2008	Average
Macro-Organic Chemistry (A)– ST							
Total tenured staff	1.05	1.05	1.45	1.45	1.45	1.45	**2.8**
PhD students	5.50	4.0	5.8	6.0	5.2	6.8	**5.6**
Post-doctoral fellows	3.9	6.4	6.3	5.2	6.8	4.9	**5.6**
Macro-Organic Chemistry(B)-BME							
Total tenured staff	1.95	1.95	1.95	1.7	1.2	1.3	**1.7**
PhD students	8.3	9.0	8.6	7.05	6.7	5.25	**7.5**
Post-doctoral fellows	2.2	2.9	2.3	1.2	2.5	4.7	**2.6**
Biomedical Image Analysis							
Total tenured staff	0.8	1.1	1.2	1.2	1.0	0.8	**1.0**
Total non-tenured faculty members	0.5	0.2	0.4	0.5	1.0	1.0	**0.6**
PhD students	6.8	6.6	8.0	10.5	10.2	11.6	**9.0**
Post-doctoral fellows	0.4	0.8	0.7	1.1	2.5	2.2	**1.3**
Biomedical NMR							
Total tenured staff	0.8	0.8	0.8	1.2	1.2	1.2	**1.0**
Total non-tenured faculty members	0.4	0.4	0.4	0.5	0.5	0.4	**0.4**
PhD students	3.6	4.0	4.3	5.7	8.6	12.0	**6.4**
Post-doctoral fellows	-	-	-	1.2	1.9	1.6	**0.8**
BioModeling and BioInformatics							
Total tenured staff	2.4	2.4	2.4	2.4	2.2	1.6	**2.2**
Total non-tenured faculty members	0.3	0.3	0.3	0.2	0.6	0.6	**0.4**
PhD students	2.4	3.2	2.8	3.7	5.6	5.8	**3.9**
Post-doctoral fellows	0.8	0.8	2.0	2.8	1.6	0.8	**1.5**
Cardiovascular Biomechanics							
Total tenured staff	1.2	1.2	1.2	1.2	1.2	1.2	**1.2**
Total non-tenured faculty members	0.3	0.3	0.4	0.4	0.4	0.6	**0.4**
PhD students	6.9	9.4	10.8	12.7	11.6	9.4	**10.1**
Post-doctoral fellows	0.2	0.8	-	-	-	-	**0.2**
Orthopaedic Biomechanics							
Total tenured staff	1.6	1.6	1.6	1.6	1.9	2.4	**1.8**
Total non-tenured faculty members	0.2	0.3	0.1	0.1	0.1	-	**0.1**
PhD students	4.0	4.1	3.4	2.4	3.4	7.4	**4.1**
Post-doctoral fellows	-	0.2	0.7	1.4	-	2.0	**0.7**
Soft Tissue Biomechanics & Engineering							
Total tenured staff	1.3	1.3	1.3	1.3	1.2	0.9	**1.2**
Total non-tenured faculty members	0.2	0.3	0.3	0.4	0.7	0.9	**0.5**
PhD students	10.6	13.6	14.2	12.6	13.2	11.7	**12.7**
Post-doctoral fellows	0.8	0.9	2.8	4.4	3	2.7	**2.4**

Table 3.2: Staff at programme level (in research fte)

Selection of full professors is done by an ad hoc advisory Committee, chaired by the Dean and consisting of at least three full professors, the Director of Education, and a number of external members from other departments within the university and from other universities. The department has an active policy of appointing part-time professors from industry, which provides a structured link with industrial applications. Recruitment of these part-time professors is done by an ad hoc advisory Committee similar to that for a full professor.

For the promotion to the position of associate professor a standing advisory Committee is in place. Assistant professors are given a temporary appointment for a four-year period, after which tenure can be granted. Each group is responsible for the recruitment of PhD students and postdoctoral researchers. Technical staff members are embedded in the laboratories which are shared by several related research groups.

PhD students work on the basis of a detailed plan stating goals for the research to be performed as well as for education. Each PhD student is part of the BEST/e institute and often of national research schools and is required to make a study plan for courses, seminars etc. After nine months a go/no go decision is made. PhD students have to give talks and present posters at national meetings and workshops, as well as international conferences.

3.6. Funding Policies

The growth of the department since its establishment in 1999 is reflected in its funding. Direct funding has grown from 7.7 M€ in 2002 to 9.5 M€ in 2008. External funding from projects has also increased strongly. Tables 3.3. and 3.4. provide an overview on funding and expenditure both at Department level and at programme level.

	2003		2004		2005		2006		2007		2008	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Funding												
Direct Funding	7,701	89%	9,050	79%	8,706	74%	8,649	67%	9,128	69%	9,507	66%
Research Funds	298	3%	1,109	10%	684	6%	1,542	12%	1,256	9%	2,212	15%
Contracts	666	8%	1,343	12%	2,394	20%	2,801	22%	2,939	22%	2,646	18%
Total funding	**8,665**	**100**	**11,502**	**100**	**11,784**	**100**	**12,992**	**100**	**13,323**	**100**	**14,466**	**100**
Expenditure												
Personnel Costs	6,423	70%	7,746	69%	8,122	67%	8,581	66%	8,847	65%	10,110	68%
Other costs	2,803	30%	3,457	31%	4,079	33%	4,396	34%	4,770	35%	4,704	32%
Total expenditures	**9,226**	**100**	**11,203**	**100**	**12,201**	**100**	**12,977**	**100**	**13,617**	**100**	**14,814**	**100**

Table 3.3: Funding and expenditure of the department of Biomedical Engineering (in k€)

Details of research and contract funding	2003	2004	2005	2006	2007	2008	average
Macro-Organic Chemistry (A+B)	126	244	426	578	793	766	489
Biomedical Image Analysis	233	258	394	514	571	493	411
Biomedical NMR	-	410	312	320	486	1,447	595
BioModeling and BioInformatics	53	73	86	191	227	338	161
Cardiovascular Biomechanics	212	366	403	402	412	430	371
Orthopaedic Biomechanics	115	212	321	547	582	845	437
Soft Tissue Biomechanics & Engineering	369	634	1040	1094	1180	1,617	989
Total Funding	1,108	2,197	2,982	3,646	4,251	5,936	**3,350**

Table 3.4: Details of research and contract funding (in k€)

The total annual budget of direct funding is divided into four parts:

- Staff salaries that are directly university funded
- Funds needed for education and overhead
- Funds assigned to the research groups for exploitation
- Discretionary funds for new research initiatives.

The main contribution to the research infrastructure originates from external (project) funding. When groups collaborate in a single external project, the funding will be attributed

to the main applicant only. Since it is the department's policy to promote interdisciplinary research, several of these projects exist.

3.7. Facilities

The research groups have an excellent laboratory infrastructure. In the period of the assessment the department has substantially built up experimental facilities, including the complete setup of the biomedical NMR facilities and the renewal of the Chemical Biology and Protein Engineering Laboratories. The department also finances an in-house ICT support group. Technical staff is embedded in the laboratories which are shared by several related research groups. The research groups share responsibility for their staff, which makes a major contribution to the flexibility and efficiency and allows the ratio of technical staff to scientific staff to be kept low.

Assessment of the Committee on quality of Resources, Funding Policies and Facilities

Overall, the staff is well-balanced, and the groups are similar in size. Funding, especially the external funding has grown considerably. Much funding comes from NWO in the form of the Veni-Vidi-Vici programme and this emphasizes the quality of the researchers and of the groups. The department does not levy overhead on external funding, which promotes long-term commitments. The external funding policy appears a group-based one rather than a department policy. The laboratory facilities are shared, without administrative body but on an ad-hoc basis. This is a great strength: it promotes collaboration, it works with short waiting times, and implies minimal administration costs.

3.8. Academic Reputation

The staff comprises one member of the Royal Netherlands Academy of Arts and Sciences (KNAW), one Spinoza Prize winner, one recipient of a starting grant by the ERC, two Vici's, six Vidi's, four Veni's and two NWO Toptalent Grant recipients. Of the total of 36 tenured scientific staff members, approximately one-third have an NWO grant. Over the period 2002-2007 a bibliometric analysis was executed by CWTS of the University of Leiden. Table 3.5. summarizes the main bibliometric indicators.

P	CPPex	Pnc	CPPex/JCSm	CPPex/FCSm	JCSm/FCSm	% self citations
602	7.74	26%	1.31	1.79	1.37	25

Table 3.5: Bibliometric indicators for the Department of Biomedical Engineering over the period 2002-2007.

The department has 602 journal publications (P), with a mean impact score corrected for self-citations of 7.74 (CPPex). The department has a journal impact level (CPPex/JCSm) of 1.31, which is above journal average impact level. Compared with the fields the departmental impact (CPP/FCSm) is at the level of 1.79. The researchers publish in journals with an impact above the field impact level (JCSm/FCSm is 1.37). The percentage of self-citations is 25%.

The number of publications (books edited by staff members, patents and proceedings) per FTE tenured staff, over the period 2003 – 2008, is 22, and the number of refereed journal articles over this period is 13.3 per tenured staff.

Assessment of the Committee on Academic Reputation
For the Department as a whole the academic reputation in terms publications is very good and in terms of citations is excellent. Also the number of researchers in the Veni-Vidi-Vici programme is large and an indicator of high quality of the Department.

3.9. Societal Relevance

Assessment of the Committee on Societal Relevance
The surroundings of the department are characterized by a very high concentration of high-tech medical technology and life sciences industry. In 2008 approximately 33% of the departmental budget came from research projects commissioned by industry and national programmes, providing evidence of the external impact of the research. The medical aspects of the research programme are also of societal relevance.

3.10. Balance of Strengths & Weaknesses
In the self evaluation the following SWOT self-analysis is provided of which the headlines are provided in this report:

Strengths
- The flat structure of the department with a small number of research groups. This results in good and fast communication, and in shared responsibility. All groups are discipline-based, but also have an orientation towards biomedical applications, and are therefore resilient to the rapid changes in subject areas.
- The financial situation is solid, with an increasing share of external funding, while the support organization is lean and efficient.
- The department has a dedicated, highly motivated, well-qualified and comparatively young faculty.
- The laboratory facilities are largely new and advanced, and are excellently located in the heart of an area with much high-tech medical technology and life sciences industry.
- The department has strong leadership and strong participation in two Research Profile Areas of the university, and in three nationwide Leading Technological Institutes.
- The research is of high level from a scientific point of view, as witnessed by the CWTS citation analysis.

Weaknesses
- The main weakness of the department is the translation and transfer of the technology to (university) medical centres, despite good contacts.

Opportunities
- The demand for healthcare solutions is growing and changing. Medical innovations must not only care for and cure people, but also save work and reduce costs
- A strong scientific base provides the opportunity to improve on the valorisation component of the research. The department aims at intensifying collaborations to ensure that knowledge and technology is shared, transferred and built upon.
- To even better exploit the high-tech strengths of the region, and to use the knowledge in the department to start more spin-off enterprises.

Threats

- Matching requirements by more and more funding agencies, which tend to act as a barrier to fundamental, high-risk and curiosity driven research.
- The declining quality of secondary education in the Netherlands, resulting in freshmen with lower levels of knowledge and skills in mathematics and physics.
- Finding suitable candidates for the large number of postdoctoral and PhD positions that will be available in the near future.
- State-of-the-art (bio)medical equipment is becoming very costly, which makes it a challenge to maintain the technology level of the laboratories at the required level.

Assessment of the Committee on Strengths and Weaknesses

The SWOT analysis is good characterization by the Department. The transfer of technology to (university) medical centres should be improved by closer collaboration with medical researchers and biology groups, as mentioned above. The threat of the poor science education of Dutch students should be converted into strength by means of internationalization. The Committee noticed the small number of foreign students and the limited attempts to hire international staff. Opportunities are indeed many and look good.

4. Assessments of the research programmes

The Committee assessed the following programmes of the Department of Biomedical Engineering at Eindhoven University of Technology:

		Quality	Productivity	Relevance	Viability
TUE1	Macro-Organic Chemistry	5	5	5	5
TUE2	Biomedical Image Analysis	5	4.5	5	5
TUE3	Biomedical NMR	4.5	4.5	4.5	5
TUE4	BioModeling and BioInformatics	3.5	4	5	4
TUE5	Cardiovascular Biomechanics	3.5	3.5	4	3.5
TUE6	Orthopaedic Biomechanics	4	4	5	5
TUE7	Soft Tissue Biomechanics & Tissue Engineering	4.5	5	5	5

The detailed assessment per programme follows in the next section of this report.

Programme TUE1: Macro-Organic Chemistry

Programme coordinator:	prof. dr. E.W. Meijer	
Research staff 2008:	24.4 fte	
Assessments:	Quality:	5
	Productivity:	5
	Relevance:	5
	Viability:	5

Short description
The research programme in Macro-Organic Chemistry aims at bridging the gap between life sciences and materials science on the one hand, and organic chemistry and polymer chemistry on the other hand, by exploratory investigations of supramolecular (bio)systems. The overall target is focused on the non-covalent synthesis of complex supramolecular objects. Both natural and artificial systems are being investigated. Exploring the many possibilities of supramolecular chemistry, the group aims at the design, synthesis, characterization and possible applications of complex molecular systems for functional materials and systems.

The research is based on three sub-disciplines:

- Biochemistry and chemical biology;
- Macromolecular and organic chemistry;
- Nanoscience and nanotechnology.

By the design, synthesis, and characterization of supramolecular multi-component objects of both biological and synthetic fragments in the 3-10 nanometer regimes, the programme aims at studying the structure and dynamics of well-defined functional objects that will lead to new applications. The programme therefore focuses on three research topics: 1) Supramolecular π-conjugated assemblies; 2) Supramolecular polymers, helical aggregates and (bio)materials; and 3) Supramolecular biomedical chemistry.

The research is performed within a variety of local and (inter)national collaborations. A number of industrial collaborations are active and will be continued. In order to be active in this broad range of topics, the programme has selected three thrust areas that provide a strong basis for the research projects, to acquire a leading international position. The three thrusts are:

- Design and synthesis;
- Self-assembly and supramolecular chemistry;
- Characterization of complex molecular systems.

Quality
The Committee was of the unanimous opinion that the work of the group of prof. dr. E.W. Meijer is of excellent quality. The group is international recognized as one of the top research groups in Supra-molecular systems. In addition to previous distinguished grants (among which the Spinoza Award: the 'Dutch Nobel prize'), Prof. Meijer was recently granted the very prestigious Advanced Grant of the European Research Council.

Productivity
The productivity is high for a group of this size. The group leader clearly focuses on quality versus quantity. The Committee wonders to what extent a better balance between PDs and PhDs (currently 8 versus 13 with a staff of 3) might be considered.

Relevance
The relevance of this research is obvious, not only from a more fundamental and curiosity driven point of view but also in respect of potential applicability to the synthesis of biomaterials. The research is well focussed in this respect and the group manages to communicate their work to the relevant 'consumers' of their fundamental work.

Viability
The group is well organized and has a strong leadership. A better ratio PD/PhD could bring some additional dynamics in the group.

Programme TUE2: Biomedical Image Analysis

Programme coordinator:	prof. dr. ir. B.M. ter Haar Romeny	
Research staff 2008:	15.6 fte	
Assessments:	Quality:	5
	Productivity:	4.5
	Relevance:	5
	Viability:	5

Short description
The research group focuses on five sub-programmes:

Scale & Orientation
The sub-programme focuses on studying modern neurophysiologic research in order to biomimic this system mathematically for the design of robust and generic algorithms. The group was specifically designed with a strong mathematical level. In the past decade great attention was paid to local analysis. The fundamental research focuses on the multi-scale and multi-orientation structure of images, and on the analysis of tensor valued images.

Multi-valued Image Analysis & Visualization
Visualization is essential in medical image analysis. The sub-programme focuses on:

- Automatic and optimal transfer function settings for 3D visualization;
- GPU programming;
- Anatomical 3D rendering;
- Mathematical Analysis of tensor fields;
- Visualization of Diffusion Tensor Imaging (DTI) data, this is the main focus.

Cardiac Image Analysis
This sub-programme focuses on heart disease; new strategies are being developed for the segmentation of the right atrium wall. This is needed to guide ablation with electrophysiology (EP) catheters. To quantify the extent of an early non-symptomatic heart infract non-invasively and without contrast, the sub-programme has designed a new, robust multi-scale application for the extraction of a dense optic from field from MRI tagging time sequences of the moving heart.

Computer-Aided Diagnosis
The sub-programme focuses on current clinical needs with high-volume data and X-Ray dose reductions. The sub-programme focuses on the following targets:

- Low dose robust polyp detection in CT virtual colonoscopy;
- Dynamic contrast-enhanced MRI for breast cancer screening;
- Cardiac left ventricle motion analysis for cardiac output calculations;
- Automatic detection of pulmonary emboli in high resolution CT,

Image-guided surgery
The sub-programme is collaborating with Maastricht University in developing projects for optimized performance and new visualization procedures using a low field interoperative MRI for neurosurgery. A local team is involved in precise navigation for deep brain

stimulation and multimodal GPU-based interactive 3D visualization for precise planning of resection surgery and contextual navigation.

Quality
The Committee was of the unanimous opinion that the work of the group of prof. dr. ter Haar Romeny is of excellent quality. The examples presented (analysis of cardiac imaging and diffusion tensor image analysis based on HARDI data) as well as the on line demonstration were very convincing. Focus of the work is the development of generic algorithmic tools, for which it is very well known and which benefits from the link to the TU/e Mathematics and Computer Science Department. Strength of the group is that despite its focus on mathematical tools it has established a strong application branch ('algorithm design need real-world problems').

The value of the research in the group is reflected by the significant number of collaborations, also with industrial partners. In addition, the group has acquired substantial external funds.

The international reputation of the group leader is very high in many areas regarding image analysis. He has taken many prestigious positions as president and member of Dutch and European Societies. Publication strategy was considered a potentially weak point, but the group has high quality publications in important journals in the field, but also many in intermediate journals.

Productivity
The productivity of the group is considered very high (number of publications and conference contributions). The work is published in good quality international journals in the respective fields. The quality of work might justify even higher ranked journals. The Committee notes that the self-assessment report lists relatively many 'lecture notes' rather than journal articles.

The group has four patents during the last reporting period, which is considered very well. This should be encouraged as intellectual property is a major asset for academia.

Relevance
The topic of the group is of high relevance. Methods to reliably and efficiently extract quantitative information from biomedical images are of ever increasing relevance. In addition translating imaging information into significant medical information is essential. The group has developed an effective balance between algorithm development and applications. This is achieved through collaboration with biological/clinical groups. Results of the work are efficiently disseminated to the scientific community (publications, presentations) and to potential stakeholders (preclinical and clinical partners).

Viability
The group is efficiently structured with a group leader and an associate and assistant professor. The leadership in the group is considered excellent.

For viability, see also the section on relevance, quantitative image/data analysis is of central importance for BME. The value of non-invasive imaging critically depends on the quality of the image analysis tools. The group is therefore essential for BME/u and has definitely a long-term perspective.

Programme TUE3: Biomedical NMR

Programme coordinator:	prof. dr. K. Nicolay	
Research staff 2008:	15.2 fte	
Assessments:	Quality:	4.5
	Productivity:	4.5
	Relevance:	4.5
	Viability:	5

Short description
The mission is to explore new biomedical applications of MRI and spectroscopy (MRS), aimed at furthering the fundamental understanding of the functional properties of biological systems *in vivo*, and addressing specific problems inspired by clinical needs. The emphasis is on the development of advanced tools for the *in vivo* quantification of biomarkers that play a vital role in skeletal muscle disorders and cardiovascular diseases. The group furthermore aims at developing powerful multimodal contrast agents and MRI detection sequences to enhance the specificity and sensitivity of MRI-based biomarker analysis in intact tissues *in vivo*. The research rests on three main pillars:

Cardiovascular disorders
The programme aims at the development of MR technologies to study the structure, the function and metabolism of the cardiovascular system in rodent models. Specialties are novel techniques for retrospective, 'wireless' gating for cardiac MRI, diffusion tensor imaging of cardiac fibre architecture and target-specific imaging of biomarkers.

Skeletal muscle disorders
The programme studies the various stages of peripheral insulin resistance, including metabolic syndrome and type 2 diabetes, and pressure sores, which all are strongly manifested in skeletal muscle. The ambition is to develop MR-based panels of non-invasive biomarkers with which the functional, structural and metabolic status of the muscle tissue can be assessed *in vivo*, thus enabling refined studies of disease mechanisms and treatment evaluation.

Molecular and cellular imaging.
The aim is to visualize biomarkers of disease processes with the use of targeted probes. MRI is relatively insensitive and powerful contrast agents are therefore needed. The programme aims to develop sensitive MRI detection schemes and to apply these concepts to the animal models of cardiovascular and skeletal muscle disorders.

Quality
The group of prof. dr. Nicolay is internationally leading in the field of preclinical Biomedical MRI and Molecular Imaging. The molecular imaging research also comprises nuclear imaging and radiochemistry to exploit the high sensitivity of SPECT and PET imaging. The group has a very good international reputation and is highly productive. This is also reflected by the large amount of external funds acquired. In particular the work regarding the development of multimodal/MRI molecular imaging probes of the group is remarkable. The imaging methods provided by the lab are practiced at the highest standards. The group has a good mix between applied projects (cardiovascular, metabolic disorders) and basic development of imaging tools (novel molecular imaging probes).

The interaction with other groups in the department (groups ter Haar Romeny, Meijers, Hilbers, and Baaijens) is essential and well established and one of the success factors of the lab. The lab presented a convincing strategy towards translational applications in conjunction with the novel imaging centre at the high tech campus. This should be supported my management. In general it should be kept in mind that imaging is a resource intense technology, maintenance of technological stat-of-the-art will ask for substantial investments in the future.

A potential issue is the rather diverse range of applications ranging from design of novel molecular imaging probes to MRI applications covering a wide range of indications (cardiovascular, muscle structure, metabolism). This is on the one hand a consequence of the group's success, and on the other hand due to the uniqueness of instrumentation. With the structure of the group comprising of two associate professors (Strijkers, Prompers), and one part-time professor (Gruell) with clearly allocated topics, the challenge is well managed. Nevertheless, it is advisable to avoid further diversification that might potentially dilute resources as it would affect the coherence of the programme.

Productivity
The productivity of the group is considered very high (number of publications, conference contributions). The work is published in highly ranked international journals in the respective fields.

Relevance
The topic of the group is of high relevance. Biomedical imaging is a key enabling technology that will impact health care at multiple levels: improved diagnostics, patient staging and stratification, evaluation of novel therapeutic approaches, patient management, etc. The group is active towards translational applications and has presented a convincing strategy in this regard (multimodal translational imaging centre at High Tech Campus Eindhoven). The group has established good relations to clinical sites such as the Maastricht University.

The Committee considers the implementation of knowledge on new development of imaging methods as good, the advancement in the molecular imaging field is considered very good. Results of the work are efficiently disseminated to the scientific community (publications, presentations) and to potential stakeholders (preclinical and clinical partners).

Viability
The group is efficiently structured with a group leader and an associate and assistant professor each, which allows coping with the diverse portfolio. It has demonstrated remarkable flexibility during the reporting period, which is definitely a strength, but bears the risk of loosing focus. The leadership in the group is considered very good.

For viability see also section on relevance: the group covers an aspects of increasing importance in BME. Non-invasive imaging is inherently translational with important contributions in many disciplines in biomedical research. The group has definitely a long-term perspective in the field.

Programme TUE4: BioModeling and BioInformatics

Programme coordinator:	prof. dr. P.A.J. Hilbers	
Research staff 2008:	8.8 fte	
Assessments:	Quality:	3.5
	Productivity:	4
	Relevance:	5
	Viability:	4

Short description
The programme aims to improve by modelling the qualitative and quantitative knowledge of biomedical processes and to educate in this field. The interdisciplinary programme integrates aspects of Mathematics, Computer Science, System and Control Theory, Engineering and Biomedical Sciences. The emphasis is on computational modelling methods and techniques especially at the molecular and cellular levels to enhance the fundamental understanding of cell metabolism and transport mechanisms in and between cells. Central themes are biomedical models, the translation of these models into algorithms, large-scale computer simulations, and quantitative analysis and interpretation of data from the modelling experiments.

The role of computer technology and modelling in biomedical engineering has met several changes in recent years. The programme has two research areas, applied in the following biomedical themes:

A. Molecular modelling
   - Atomistic simulations
   - Coarse grained simulations
   - Micro-transport systems simulations

B. Systems Biology
   - (Metabolic) Systems Biology
   - Cell signalling networks

Quality
This is clearly a research group in transition coming from Computer Science and transforming into Biomedical Computational Science. This implies a serious reorientation over the evaluation period, which resulted in a qualitative less optimal output. The group has a very high potency to excel but for that more effort needs to be on publishing in high quality international journals instead of conference proceedings. The international visibility of the group, e.g. through invited and keynote lectures as well as international positions on editorial boards, is still limited.

Productivity
Given the small size of the group the productivity is very good, we strongly advice however to focus more on publishing in high impact journal papers.

Relevance
The Committee considers the research of this group to be very relevant in general and specifically in the department of biomedical engineering. Modelling and simulation is one

of the major ways to drive new experiments and to capture critical processes and to reason about the immense complexity that is implied in biomedical research. We advise the group to seek further connections with biomedical research groups and to look for collaborations in the international physiome research society (e.g. the VPH initiatives).

Viability
The structure of the group will gain from a better ratio PD/PhD (Currently 1.5 versus 4). Especially for a group in transition Postdocs can provide the essential knowledge and momentum needed. The amount of EU and NWO funding requires some attention, for a group in this high profile research area there are good ways to increase the contract and research grants. In addition to that the possibility for individual grants such as Veni-Vidi-Vici and (beginning) ERC could actively be pursued.

Programme TUE5: Cardiovascular Biomechanics

Programme coordinator:	prof. dr. ir. F.N. van de Vosse	
Research staff 2008:	11.2 fte	
Assessments:	Quality:	3.5
	Productivity:	3.5
	Relevance:	4
	Viability:	3.5

Short description
The mission of the programme is a to provide education and to perform research in the field of cardiovascular biomechanics so as to promote the use of experimentally validated predictive mathematical modelling, both in diagnosis and selection of therapy in clinical practice, and in research an development in the medical device industry. In cardiovascular biomechanics, fluid dynamics (hemodynamics) and solid mechanics (vascular and cardiac mechanics) meet where both fluid (blood) and solid (cardiovascular tissue) are complex and dynamic in structure and nature. A chain of four dedicated mutually related research areas readily evolves from the definition of cardiovascular research. This chain is used to structure the research of the Cardiovascular Biomechanics group and to put research activities that come with the mission statement into practice. The four research areas are:

- Hemodynamics
- Mechanics and adaptation
- Instrumentation and devices
- Clinical Research

Quality
The overall quality of this programme is of some concern. The concern is not about the technical expertise, but rather more about the unclear linkage among the modelling, experimental and clinical applications. The major strength of the programme clearly resides in its high level of technical expertise in mathematical modelling, specifically of the fluid/structure interactions as they pertain to the cardiovascular system. This facet is in line with one portion of the stated mission of the programme. However, how other aspects of the mission, that is, experimental validation of the model predictions with an eye toward diagnosis and affecting treatment can be directly tied to the modelling is not so evident. One example relates to the stress analysis of abdominal aortic aneurysms. Their theoretical model is correct but cannot be validated since the 'unloaded' state cannot be obtained *in vivo*. Without this critical piece of information, it is not clear how clinical intervention can be influenced.

The above concern is likely also contributing to what is perceived to be a rather low impact of the programme. This is reflected among all the members of the group having not only a low total scientific output (see below) but also a low number of total citations and low number of highly cited publications. Consequently, the H-indexes of the tenured faculty, including the programme leader, are below what one would expect of a world-class group. The leader of the coronary hemodynamics research stands out very positively.

There is also some concern that the group is trying to do too much for its size. This makes it difficult for them to compete effectively with others who focus more narrowly on fewer research areas.

The fact that experimental and clinical aspects comprise a large portion of the research, explains the seemingly low overall external funding for the group. It is recognized that some sources of clinical funding are not reflected in the data presented in the self-assessment. The EU grant for the training programme MeDDiCA is an indication of international recognition of quality.

Productivity
The total scientific output of the programme is low. This is true whether one considers all academic publications or only refereed journal articles (which is the normal avenue for reporting research findings for this field) and regardless of whether one counts absolute numbers or normalized (full-time FTE, tenured FTE, total FTE, etc.) output. This low output exists despite the fact that this programme has one of the higher fractions of PhD students among all the programmes. Somewhat mitigating this concern is a trend over the past two years (2008 and 2009) of increasing numbers of refereed journal articles.

The distribution of journal publications seems to reflect a reasonable balance among the major research thrusts of the programme. However, there is some concern that, over the time period covered by this review, only about one-fourth of the refereed journal articles were not co-authored by the programme director.

Relevance
The general mission of the group is laudable, and there is no doubt that their research has and will continue to advance basic scientific knowledge. There is collaboration with the clinic (mainly Maastricht and Catharina Hospital Eindhoven), but except for the work with Pijls, it is still not clear that they will achieve the goal of having their technical approach impact clinical diagnosis and/or treatment.

Their expertise needs to be better and more widely disseminated to the world-wide audience. There is most of all a clear need for concrete and compelling plans to better link the fundamentally sound scientific goals of the research with implementation. It is advised that, through the collaboration with the clinical groups, attention is given to the production of high quality publications. A very positive example is seen in the work of Professor Pijls.
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Viability
Because of the low impact of the programme and the rather unclear manner in which scientific findings are to be implemented for diagnosis and treatment, the long-term viability of the programme is of concern. In external funding the tenured staff should apply as first (leading) applicant, and more personal grants should be obtained to improve viability. There is also some concern about the leadership of the group. One manifestation of this is the fact that there are no associate professors in the group. Both tenured professors, despite having been faculty for many years, are still at the assistant professor level. This suggests that there could be problems down the road for keeping the group viable. If one of the tenured faculty members leaves the group, not only could this cripple the research but there could also eventually be a leadership void. A viable recruiting and succession planning scheme as well as a cogent mentoring and recruiting plan for the group should be formulated and implemented.

Programme TUE6: **Orthopaedic Biomechanics**

Programme coordinator:	prof. dr. ir. R. Huiskes; prof. dr. K. Ito (since September 2007)
Research staff 2008:	11.8 fte
Assessments:	Quality: 4
	Productivity: 4
	Relevance: 5
	Viability: 5

Short description
The field of bone and orthopaedic biomechanics is directed towards mechanics and biology of bone, in relation to prevention, diagnosis and treatment of medical conditions and diseases of the musculoskeletal system. Both basic and applied research projects are conducted. Present research activities can be categorized into five sub-programmes:

- Mechanobiology of bone modelling & remodelling
- Imaging & computational assessment of bone fracture risk
- Mechanobiology of tissue differentiation
- Osteoarthritis & artificial joints
- Cold plasma treatment in medicine and biology

Quality
The former leader was belonging to the top of the field world wide, and for many years he was the editor of Journal of Biomechanics. This leader recently stepped down and was succeeded by prof. Ito. In the discussion with prof. Ito it became clear to the Committee that he, with both a Ph.D. degree and an M.D. degree, has clear plans in mind. He will be able to open contacts with the clinic easily (with Nijmegen and Maastricht, renewed contact) that were until now limited. The quality of the publications is good and the publications are in good journals.

Productivity
The number of publications per tenured staff (in fte) and per year is 8.8, and is sufficient. The number of Ph.D. students is on average 4 and as a consequence the number of dissertations is about 1 per year. Attention will and should be paid to the increase in external funding.

Relevance
Relevance is good but relations with the clinic should be improved. Increase in the relations with industry is planned, but Dutch industry, is weak in the field of orthopaedics and collaborations with international industrial partners are rather difficult (procedures and legal issues). While departments of biology and medicine are missing in the technical university, 'NL is flat and small and easy to get around, and therefore is not a big obstacle'.

Viability
The past performance of the group, the clear strategy for the research, the international cooperative network, as well as the outlook for funding, show the high viability of the research programme.

Professor Ito has the right vision and appears to be a good leader. He stands behind his staff. He will be able to build bridges to the clinic. He has the perception and daring to stop a project/area when needed. He takes advantage of the fact that he is new to the system.

Besides the chair holder, other members of the group are visible (two vidi awards: Van Rietbergen and Van Donkelaar). Professor Ito has clear ideas about the future of his staff members, to improve their positions. If someone is ready for a next step and the department is not able to keep him/her, this person should go elsewhere.

Conclusion
Mechanobiology is an important subject with adequate cellular and molecular support. However, in the future it might become insufficient, but then steps will be taken to increase the support. Thus, this is a very interesting area of research with much potential. The group is good and the new leader appears able to maintain the high quality. Attention should be paid to clinical collaboration.

Programme TUE7: Soft Tissue Biomechanics & Tissue Engineering

Programme coordinator:	prof. dr. ir. F.P.T. Baaijens	
Research staff 2008:	16.2 fte	
Assessments:	Quality:	4.5
	Productivity:	5
	Relevance:	5
	Viability:	5

Short description
The mission is to conduct multidisciplinary research on the biomechanics and mechanobiology of soft biological tissues with application to the engineering of living, load-bearing cardiovascular tissues, and to provide a stimulating educational environment for graduate and post-graduate students. Special emphasis is given to the integration of computational modelling with molecular and cell biological concepts. The programme has three themes:

- Tissue Engineering
- Soft Tissue Biomechanics
- Multi-phase Mechanics (until mid 2007, thereafter continued in group of prof. dr. K. Ito, TUE6)

Quality
This is a relatively young but strong programme with the main focus on soft tissue mechanics and tissue engineering of heart valves and, more recently, on myocardial tissue. The tissue engineering work is characterized (and distinguished from other groups in other countries) by an extremely strong grounding in solid mechanics. This certainly derives from many in the group having backgrounds in mechanical engineering. In contrast, many other tissue engineering groups are grounded in chemical engineering. Likely because of this strong mechanical engineering component, the work on tissue valves is among the forefront of those in the world. While the work is likely to have a large impact down the road, it is only beginning to be recognized. Once the durability of the valve is proved, the group should finally achieve the more widespread recognition it deserves. The myocardial research work is at an earlier stage but, because of the new faculty with a stronger biological background, should eventually also prove to be a leading group. Whether this brings enough biological expertise to the group is not clear but it is evident that some of the necessary expertise is available through extensive collaborations. The work on ulcers is not viewed to be as cutting edge or impactful as the tissue engineering work.

Productivity
The group has been very productive (well above the departmental average) throughout the review period both in terms of absolute and normalized publications and journal articles. There are no concerns in this regard.

Relevance
The research of the group, although still in early stages, is clearly highly relevant both in terms of advancing and disseminating basic knowledge. The path and desire toward implementation is clear and initial steps have been taken with the formation of a spin-off

company. However, it is yet too early to determine whether and in what specific form the implementation of knowledge will eventually occur.

Viability
The director was previously the dean of the department and is currently heavily involved in two non-university based institutes. Nevertheless, it is clear that he is able to devote the requisite time to lead the group, to oversee the research of the group as well as to identify, recruit and mentor young faculty. The fact that faculty in the group has recently received a Vici and two Veni awards is a good sign of the long-term viability of the group.

Appendices

Appendix A: Curricula vitae of the Committee members

Professor Nico Westerhof (chairman) studied experimental physics in Utrecht and received his MS degree in 1962. From 1964 to 1966 he worked in the Department of Physiology of Georgetown University in Washington D.C. In 1966 he started at the Department of Biomedical Engineering of the Moore School of Electrical Engineering of the University of Pennsylvania, Philadelphia Pa, where he received his Ph.D. degree in Biomedical Engineering, in July 1968. In 1969 he moved to Amsterdam, the Netherlands, and joined the Department of Physiology of the Vrije Universiteit. He became Lecturer in 1971 and Professor in 1980. From 1992 to 2002 he was Scientific Director of the Institute for Cardiovascular Research of the Vrije Universiteit (ICaR-VU). He became emeritus 31 May 2002. In 1996 he received an honorary doctorate from the Ecole Polytechnique Fédérale de Lausanne, Switzerland. In December 2009 he was recipient of the 'Oeuvre-prize' of the Netherlands Society of Physiology. He is honorary member of the Italian Society for Experimental Biology, and member of the Turin Medical Academy of Sciences (Accademia di Medicina di Torino). He was President of the Cardiovascular System Dynamics Society (1996-1998). His research interests are the cardiovascular system in general. He is particularly interested in the interaction between the arterial system and the heart in relation to (pulmonary) hypertension, including modelling both systems. He also studies the coronary circulation. Since October 2006 he performs, part-time, research on pulmonary hypertension in the Department of Pulmonary Diseases of the VUmc, Amsterdam.

Professor Markus Rudin is full professor for Molecular Imaging and Functional Pharmacology at the Swiss Federal Institute of Technology (ETH) and the University of Zürich, at the institute of Biomedical Engineering. Rudin received his PhD in 1981 at the Laboratory for Physical Chemistry of ETH Zürich. In 1997 he received a Venia legendi (assistant professorship) at the University of Basel. He has worked at Sandoz Pharmaceuticals between 1983 and 1996, first as head of the MRI Group and later as head of the Biophysics Unit. In 1997 he started working for Novartis Pharma AG in Switzerland. He first became head of the In-vivo Models Unit, in 2000 he became head of the Analytics and Imaging Sciences Unit. He has published over 120 peer-reviewed publications, was editor of four books and has written a textbook on Molecular Imaging. Rudin is often invited at international conferences to give lectures (over 70). In 1981, he won the ETH Silver Medal for his PhD thesis, in 2003 he won the Novartis Leading Scientist award and in 2005 he was elected in the Research Council of the Swiss National Science Foundation.

Professor Peter Sloot is full professor in Computational Sciences at the University of Amsterdam. He has MSc degrees in Chemistry (1983) and in Physics (1983). Sloot received his PhD (1988) in Computer Science. He was research assistant at the Dutch Cancer Institute, held research positions at the University of Amsterdam and at Calltech (USA). He was Scientific Advisor of MacNeal-Scwendler Company, Scientific Board member Biocomputing (Virology Networks), and chair of the Scientific Advisory Committee of the ASCI KNAW before he became a full professor in 2001. He is furthermore on the advisory board of the Informatica kamer and of the Lorentz centrum. His research is focused on trying to understand how nature processes information. He studies this 'natural information processing' in complex systems by computational modelling and simulation, as well as through formal methods. His work is applied to a large variety of applications with

a focus on (but not limited to) Biomedicine. His recent work is on modelling the virology and epidemiology of infectious diseases, notably HIV. In his work he tries to build bridges to socio-dynamics. Currently, he is leading two large EU projects: ViroLab and DynaNets and is supervising research from various NIH, NSF, NWO and Royal Academy projects. Sloot has published over 430 papers, books and edited volumes. He has also given over 20 radio and TV interviews on various scientific results. He has received many honours and awards, for example visiting professor at Santa Fe Institute, at Bandung Indonesia, at Griffith University, Brisbane Australia, and at NTU Singapore. He was also NNV distinguished professor Computational Sciences in 1996 and received the WorldComp 2009 award (Las Vegas).

Professor Frank Yin is chairman of the Department of Biomedical Engineering and Director of the Institute of Biological and Medical Engineering at Washington University in St. Louis. Yin received his PhD (1970) and MD (1973) from the University of California, San Diego. After completing house staff training at UCSD and postdoctoral training at the National Institute of Aging, he served on the faculty at Johns Hopkins University from 1978 to 1997 when he moved to Washington University to head the new department. His research interests include soft tissue mechanics, cardiovascular mechanics and hemodynamics. Most recently he has been interested in cellular mechanics, particularly with respect to the mechanical properties of actin stress fibers probed with atomic force microscopy. He has co-authored more than 130 peer-reviewed articles and in edited one book published V*entricular/vascular Coupling: Clinical, Physiological and Engineering Aspects*, published by Springer-Verlag in 1987. He has been editor-in-chief of the American Society of Mechanical Engineers' Journal of Biomechanical Engineering, president of the Biomedical Engineering Society, and is a fellow of the ASME and American Institute of Biological and Medical Engineering. He has served on numerous advisory boards for biomedical engineering departments including those at the University of Pennsylvania, University of Rochester and Georgia Institute of Technology; was a founding National Council member of the National Institute of Biological Imaging and Bioengineering; and served as a member of an advisory panel to the President to evaluate the Engineering School at City University of Hong Kong in 2009.

Appendix B: Explanation of the SEP scores

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

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

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

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

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