Assessment report
Limited Programme Assessment

Master Embedded Systems

Eindhoven University of Technology

Contents of the report

1. Executive summary

In this executive summary, the panel presents the main considerations which led to the assessment of the quality of the Master Embedded Systems programme of Eindhoven University of Technology, which has been assessed according to the NVAO Assessment Framework.

The panel noted programme management followed up on the recommendations, made by the previous external assessment panel, such as strengthening the embedded systems orientation of the programme. In addition, programme management introduced a number of improvements, such as extending the common core in the curriculum and tailoring the homologation courses to the students' needs.

The programme's name, Master Embedded Systems, matches its contents and corresponds to the names of similar programmes.

The panel considers the Master Embedded Systems programme of Eindhoven University of Technology to be an internationally distinctive and attractive programme and welcomes the objective to offer a dedicated embedded systems programme. The panel feels, however, the potential of the programme could be more fully exploited by further strengthening the collaboration of the programmes of the three Universities of Technology in the Netherlands in order to, among others, offer students the range of subjects available at these different Universities.

The panel is positive about the Domain-specific Frame of Reference Embedded Systems which has been drafted by management of the three programmes. The domain has been adequately described and the programme has been appropriately compared to authoritative international sets of requirements.

The panel approves of the intended learning outcomes of the programme, as these cover domain-specific knowledge and skills, research competencies and academic skills to be achieved by students adequately. The intended learning outcomes meet the requirements of the Domain-specific Frame of Reference and match the requirements of an academic master programme. The panel considers the intended learning outcomes of the programme to prepare students for positions in research and industry alike.

The participation of industry in the programme is satisfactory, to be deduced, among others, from the position of the External Advisory Board within the programme.

Considering the admission requirements and admission procedures of the programme to be appropriate, the panel welcomes the on-line homologation tool and the on-line homologation courses offered to the students to remedy their deficiencies in either computer science or electrical engineering. The panel is positive about the pre-master programme.

The panel considers the intended learning outcomes to be met in the curriculum. The correspondence of learning outcomes and curriculum components is, however, addressed at a rather high aggregation level. The panel recommends to draft these relations in a more detailed way, in order to be able to identify more clearly overlap of and gaps between courses from the intended learning outcomes perspective.

The panel regards the curriculum of the programme to be very adequate and is especially positive about the specialisation courses in the four streams in the curriculum, which are strongly embedded systems-related. The internship requirements and the design of the graduation projects are adequate as well. The research knowledge and skills are covered appropriately. Although the panel is positive about the common core courses contents, it is advised to adapt these to offer students a more comprehensive view on the embedded systems domain. The panel considers the EIT Digital Embedded Systems track to be strongly focused on the embedded systems domain and to strengthen the international dimension of the programme.

The panel assesses the educational principles and the study methods of the programme as adequate and to assist students in their learning processes. The panel considers the blended learning activities in the programme to be positive and advises programme management to continue the blended learning projects and experiments in collaboration with the other Universities.

The study guidance in the programme is considered by the panel to be appropriate. The student-to-staff ratio is adequate. The panel welcomes the generous number of hours of face-to-face education in the curriculum.

The panel is very positive about the lecturers in the programme. They are experts in their fields. All of them have PhD's and a substantial number of them possesses BKO-certificates. Being impressed by the comprehensiveness of the University BKO-course, the panel appreciates the University policy to require all new staff to obtain the BKO-certificate.

The panel concludes the facilities for the programme to be very good.

The panel considers the programme examination and assessment rules and regulations to be appropriate. They comply with assessment policy statements of the two departments involved and meet the Eindhoven University of Technology examination framework.

The responsibilities of the Examination Committee are adequate, since they include monitoring the examinations and assessment procedures, the quality of the examinations and the students' achieving the intended learning outcomes of the programme. The panel especially appreciates the role of the Quality Assurance Committee in regularly inspecting samples of both examinations and master theses on behalf of the Examination Committee.

The examination methods meet the curriculum components learning goals and are satisfactorily diverse.

The panel considers the examinations and assessments procedures to be appropriate, as these procedures ensure the validity, reliability and transparency thereof satisfactorily. The assessments of the internships are regarded by the panel to be adequate. The assessment procedures for the master thesis projects are not doubted by the panel. The panel would, however, like to make some suggestions for further improvements, being to fill out the thesis assessment forms more elaborately to allow for more clear substantiation of the grades given, to better align the grading of the projects conducted in industry and those done in research environments at the University and to verify whether industry representatives may be members of the thesis assessment committee.

The examinations of the courses of the programme are assessed by the panel to be satisfactory. Having studied a total of fifteen master theses of graduates of the programme, the panel concluded these to be up-to-standard, meeting the learning outcomes of the programme. None of the theses has been assessed by the panel to be unsatisfactory and quite a number proved to be good or very good. The panel confirms the relatively high grades given for the theses.

The information provided on the graduates' careers leads the panel to consider the graduates to be well-prepared for the positions in this field on the academic master level. The careers show the graduates to meet the demands of industry as well as those of the academic world. The views expressed by the representatives of industry echo these positive findings.

The panel assesses the Master Embedded Systems programme of Eindhoven University of Technology to be satisfactory and recommends NVAO to grant re-accreditation to this programme.

Rotterdam, 13 September 2017

Prof. dr. ir. D.R.M. Stroobandt   drs. W. Vercouteren
(panel chair)   (panel secretary)

2. Assessment process

Certiked VBI received a request by Eindhoven University of Technology to conduct a limited programme assessment for the re-accreditation of the Master Embedded Systems programme.

Certiked requested the approval by NVAO of the proposed panel of experts to conduct this assessment. NVAO have given their approval. The panel composition was as follows (for more detailed information please refer to Annex 4 Assessment panel composition):
- Prof. dr. ir. D.R.M. Stroobandt, full professor Embedded Systems and Hardware Design, Ghent University (panel chair);
- Prof. dr. P. Marwedel, full professor Methods for Computer-aided Design of Integrated Circuits, Dortmund University of Technology (panel member);
- Dr. A.D. Pimentel, associate professor in System and Network Engineering Lab, University of Amsterdam (panel member);
- S. de Vries, general manager of the private company Chess Wise BV (panel member);
- E.E.M. Leo BSc, student Master programme Educational Sciences, University of Amsterdam, (student member).

On behalf of Certiked, drs. W. Vercouteren was responsible for the process coordination and for drafting the panel's report. All panel members and the secretary signed a statement of independence and confidentiality.

The panel conducted this assessment on the basis of the standards of the NVAO Assessment Framework of 19 December 2014 (Staatscourant nr. 36791).

The following procedure was adopted. The panel members studied the documents presented beforehand by programme management, including a number of theses (please refer to Annex 2 and 3: Documents reviewed and Theses reviewed). With respect to the selection and study of the theses, the panel proceeded in line with the NVAO Guidelines for the assessment of final projects during external assessments of 18 February 2015.

Before the date of the site visit, the panel chair and the panel secretary met to discuss the assessment procedures. Before the site visit date, all panel members sent in their preliminary findings, based on the information file submitted by the programme management, sent in a number of questions to be put to the programme representatives on the day of the site visit and presented their findings about the theses, they had studied. The panel secretary summarised this information.

On 25 June 2017, the panel had a meeting to discuss the preliminary findings concerning the quality of the programme. During this preliminary meeting, the findings of the panel members, including those about the theses were discussed, and a number of questions were added to the list drafted beforehand. On the basis of this input, the panel secretary drew up a final list of questions, which served as a starting point for the discussions with the programme representatives during the site visit.

On 27 June 2017, the panel conducted a site visit at the Eindhoven University of Technology campus. The site visit schedule was in accordance with the schedule drafted beforehand (please refer to Annex 1 Site visit schedule). Programme management communicated the open office hours to the students and staff of the programme. No persons took the opportunity to meet with the panel.

In a closed session at the end of the site visit, the panel considered every one of the findings, weighed the considerations and drew conclusions regarding the quality of the programme. At the end of the site visit, the panel chair presented a broad outline of the findings to programme management.

Due to serious personal circumstances problems, the student member of the panel could not attend the site visits nor could she be present during the preliminary meeting of the panel. Having been informed about the absence of the student member, programme management agreed to proceed with the site visit as planned. The panel chair and the panel members also were in agreement to proceed with the site visit. At the completion of the assessment process, the panel agreed this process to have been conducted in a sound way.

A draft version of this report was finalised by the secretary, having taken into account the findings and considerations of the panel. The draft report was sent to the panel members, who studied the draft report and made a number of changes. The student member participated in this process. She found the assessment report to be a clear account of the panel findings and agreed to the panel considerations and recommendations. Thereupon, the secretary edited the final report. This report was presented to programme management to be corrected for factual inaccuracies. After having been corrected for these inaccuracies, the report was sent to the University's Board to accompany their request for re-accreditation of this programme.

3. Overview of the programme

3.1 Basic information about the programme

Administrative information about the programme:

Name programme in CROHO:	M Embedded Systems
Orientation, level programme:	Academic Master
Grade:	MSc
Number of credits:	120 EC
Specialisations:	Systems on Chip, Embedded Software, Embedded Networking, Cyber-Physical Systems
Location:	Eindhoven
Mode of study:	Full-time (language of instruction: English)
Registration in CROHO:	60331

Administrative information about the institution:

Name of institution:	Eindhoven University of Technology
Status of institution:	Government-funded University
Institution's quality assurance:	Approved

Quantitative data about the programme

Percentage of students who completed the programme in three years (n+1)

Cohort	2011	2012	2013
Percentage of students	74 %	65 %	63 %

Lecturers' qualifications

Qualification	MSc	PhD	BKO
Percentage of lecturers	100 %	100 %	58 %

Whereas 58 % of the lecturers are BKO-certified, 68 % of the lecturers possess qualifications to teach.

The student-to-staff ratio is 17.6.

Number of contact hours per week for each of the years of the programme

Year of the programme	Year 1	Year 2
Number of contact hours per week	17.7	7.2

3.2 Main facts about the institution

The Master Embedded Systems programme is a programme of the Department of Mathematics and Computer Science of Eindhoven University of Technology in collaboration with the Department of Electrical Engineering of the University.

According to their website, the mission statement of Eindhoven University of Technology is to be a leading, international, in engineering science and technology specialised research University. The University wants to offer excellent teaching and research and thereby contribute to the advancement of technical sciences and research in the Eindhoven region and in the world as a whole. The education, research and knowledge valorisation activities of the University are meant to contribute to the solution of major societal issues in the areas of energy, health and smart mobility, to foster the development of technological innovation in cooperation with industry and to strengthen the progress in engineering sciences through excellence in key research areas and through innovation in education.

Eindhoven University of Technology comprises nine departments, being the Departments of Biomedical Engineering, Built Environment, Electrical Engineering, Industrial Design, Industrial Engineering & Innovation Sciences, Chemical Engineering & Chemistry, Applied Physics, Mechanical Engineering and Mathematics and Computer Science. These departments offer 11 Bachelor programmes and 22 Master programmes. More than 11,000 students study at Eindhoven University of Technology, nearly 7,000 of them being Bachelor students and nearly 5,000 of them being Master students. There are more than 1,400 PhD-students.

3.3 Intended learning outcomes

The intended learning outcomes of the programme are as follows.
- The graduates of the programme have an all-embracing view on embedded systems, their design and their application in systems of various sizes (e.g. from small robots to cyber-physical and networked systems) including their evolution over time, demonstrated by an integration approach in system design.
- The graduates of the programme are capable of analysing the functional behaviour of complex embedded systems in a structural way using appropriate abstractions.
- The graduates of the programme are able to describe and study the non-functional aspects of embedded systems, e.g. resource boundedness and dependability.
- The graduates of the programme have a thorough knowledge of state-of-the-art methods and techniques for embedded systems design such as requirements engineering, hardware-software integration, performance modelling and analysis, validation and testing.
- The graduates of the programme are able to design embedded systems that satisfy the functional and non-functional requirements, taking into account the performance of the system during its lifetime. The graduates are also aware of costs and environmental issues making optimal use of available resources.
- The graduates of the programme have the ability to include other disciplines or involve practitioners of these disciplines in their work, where necessary. As engineers they are therefore able to work in a multidisciplinary setting.
- The graduates of the programme are able to conduct research and design independently and have a scientific approach to complex problems and ideas.
- The graduates of the programme possess intellectual skills that enable them to reflect critically, reason and form opinions.
- The graduates of the programme have the ability to communicate the results of their learning, thinking and decision-making processes at an international level.
- The graduates of the programme are aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in their scientific work.

3.4 Outline of the curriculum

In the table below, the programme curriculum is presented.

Curriculum components	Credits
Homologation courses	5 EC
System Validation	5 EC
Quantitative Evaluation of Embedded Systems	5 EC
Embedded Computer Architectures	5 EC
Real-time Systems	5 EC
Embedded System Laboratory	5 EC
Mandatory stream courses	15 EC
Stream electives	15 EC
First Year	60 EC
Internship/Electives	15 EC
Stream elective	5 EC
Graduation Project (preparation phase)	10 EC
Graduation Project (thesis project)	30 EC
Second Year	60 EC
Total credits of the programme	120 EC

The European Institute of Innovation and Technology Digital Embedded Systems track is shown below.

Curriculum components	Credits
Homologation courses	5 EC
System Validation	5 EC
Quantitative Evaluation of Embedded Systems	5 EC
Embedded Computer Architectures	5 EC
Real-time Systems	5 EC
Embedded System Laboratory	5 EC
Technology Entrepreneurship	5 EC
CTEM Project	10 EC
Winter + Summer School	5 EC
Electives	10 EC
Entry point	60 EC
Architecture of Distributed Systems	5 EC
Networked Embedded Systems	5 EC
Internet of Things	5 EC
Electives	9 EC
Innovation and Entrepreneurship Thesis	6 EC
Graduation Project (thesis project)	30 EC
Exit point	60 EC
Total credits of the programme	120 EC

4. Overview of assessments

Standard	Assessment
Standard 1. Intended learning outcomes	Satisfactory
Standard 2: Teaching-learning environment	Good
Standard 3: Assessment	Satisfactory
Standard 4: Achieved learning outcomes	Satisfactory
Programme	Satisfactory

5. Findings, considerations and assessments per standard

5.1 Standard 1: Intended learning outcomes

> *The intended learning outcomes of the programme have been concretised with regard to contents, level and orientation; they meet international requirements.*

Findings

Embedded systems are hardware/software systems which are built into devices or systems. Embedded systems fulfil dedicated functions within larger mechanical or electrical systems and control the quality and functionality of these systems or devices.

The main objectives of the Master Embedded Systems programme are to educate students in the academic and professional competencies for the design of embedded systems. Students are trained in domain-specific knowledge and skills with respect to embedded systems, this knowledge and these skills being multidisciplinary and being derived from the electrical engineering and computer science disciplines.

The programme is the result of the collaboration of the Master Embedded Systems programmes of University of Twente, Eindhoven University of Technology and Delft University of Technology. These programmes together drafted the Domain-specific Frame of Reference Embedded Systems, compiled identical intended learning outcomes for all programmes and designed curricula, to a large extent similar. Management of the three programmes meet regularly to discuss the adjustment of the programmes. The three Universities decided, however, not to pursue a joint-degree programme, allowing each of the programmes some leeway in design and delivery.

In the Domain-specific Frame of Reference Embedded Systems, management of the three programmes specified the embedded systems domain. The programmes are in line with noted international sets of requirements for embedded systems programmes, such as those of the Embedded Systems Special Interest Group (ARTIST) and the European Association for Research and Development in Embedded Intelligent Systems (ARTEMIS).

Programme management drafted the intended learning outcomes (please refer to the complete list in section 3.3 of this report). As has been mentioned, these are identical for all three programmes of the collaborating Universities. In the intended learning outcomes, domain-specific knowledge and skills, design and research competencies, critical reflection skills, communication and collaborating skills and ethical and societal awareness are addressed. Programme management has demonstrated the intended learning outcomes to meet the domain-specific frame of reference requirements. In addition, programme management has shown the intended learning outcomes to comply with the Meijers criteria, being the Dutch Universities of Technology standard for the master level of the learning outcomes.

For the three programmes, a joint External Advisory Board is in place, with members representing industry. The members of the Board with whom the panel met, indicated the Board to be effective in voicing the industry's views on the programme.

Considerations
The panel approves of the objectives of the Master Embedded Systems programme of Eindhoven University of Technology. The panel considers this programme to be internationally a distinctive and attractive programme and welcomes the goal to offer a dedicated embedded systems programme. The panel feels, however, the potential of the programme could be more fully exploited by further strengthening the collaboration of the programmes of the three Universities in order to, among others, offer students the wide range of subjects of the three different Universities. The panel noted the number of students taking courses at other Universities at this moment to be quite limited.

The panel is positive about the Domain-specific Frame of Reference Embedded Systems which has been drafted by management of the three programmes. In this frame of reference, the embedded systems domain has been adequately described and the programme objectives have been appropriately compared to authoritative international sets of requirements.

The panel approves of the intended learning outcomes of the programme. These cover the domain-specific knowledge and skills, research competencies and academic skills to be achieved by students adequately.

The panel observed the intended learning outcomes to meet the requirements of the Domain-specific Frame of Reference Embedded Systems. They also comply with the Meijers criteria of the Dutch Universities of Technology and, therefore, to meet the requirements of an academic Master programme.

The panel considers the intended learning outcomes of the programme to prepare students for positions in research and industry alike. The participation of industry in the programme is satisfactory, to be deduced, among others, from the position of the External Advisory Board within the programme.

Assessment of this standard
These considerations have led the assessment panel to assess standard 1, *Intended learning outcomes*, to be satisfactory.

5.2 Standard 2: Teaching-learning environment

The curriculum, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes.

Findings
The Master Embedded Systems programme is a programme of the Department of Mathematics and Computer Science in collaboration with the Department of Electrical Engineering, both departments of Eindhoven University of Technology. Management of the programmes of the three Universities meet regularly to discuss the alignment of the programmes. In November/December of the first year, students from all three programmes meet in the *Embedded Systems Student Event*. The Eindhoven University of Technology Master Embedded Systems programme is part of the Computer Science Graduate Programme, which includes three programmes. The structure of these programmes is determined by the Eindhoven University of Technology-wide Graduate School. The Master Embedded Systems programme is managed by the programme manager. Students and lecturers are represented in the Programme Committee, which counsels programme management on quality issues. The joint External Advisory Board of the three Universities advises programme management on the alignment with the professional practice. The Examination Committee oversees the examinations and assessments of the programme.

The number of students enrolling in the programme increased over the years, going from an influx of 34 students in 2011 via an influx of 39 students in 2013 to an influx of 74 students in 2015. The proportion of foreign students is substantial and fluctuates around 75 %. Quite a number of foreign students enter the programme via the European Institute of Innovation and Technology (EIT) Digital Embedded Systems track. The proportion of female students in the total inflow is about 10 % to 15 %.

Students with bachelor degrees in computer science or electrical engineering or equivalent qualifications are admitted directly to the programme. Programme management offers students an on-line tool to assess their deficiencies in electrical engineering or computer science. In case students report deficiencies, they are required to take homologation courses to a maximum of 10 EC. Students studying in Eindhoven may include these courses in their bachelor programme. Programme management provides on-line homologation courses. Students reporting more than 15 EC of deficiencies or students having vocational bachelor degrees should take the pre-master programme before being admitted to the programme. Students entering the programme are, in the first year, automatically registered at the other two Universities as well, this allowing them to take courses there.

Programme management showed in diagram form the relations of the curriculum components to the intended learning outcomes. From this diagram, it may be deduced all intended learning outcomes are adequately represented in the curriculum. This applies to the regular programme as well as to the EIT Digital Embedded Systems track.

The curriculum consists of common core courses (25 EC), specialisation or stream courses (15 EC mandatory courses and 20 EC electives), internship (15 EC, optional) and graduation project (10 EC for preparation phase and 30 EC for thesis project). In addition, students may take homologation courses. The five core courses are shared by the three Universities and have similar learning goals. The core courses address, among others, design and testing methods, hardware architectures and real-time systems design and analysis. One of the core courses, *Quantitative Evaluation of Embedded Systems*, is jointly designed and delivered by the three programmes. For the specialisations, students may select one of the streams offered in the programme, these being *Systems on Chip*, *Embedded Software*, *Embedded Networking* and *Cyber-Physical Systems*. Internships are offered but not frequently taken by students. Programme management ensures internship assignments to be approved, internships supervised and internship results assessed by the supervisor. The graduation projects include the preparation phase, which encompasses a literature study and a project plan and the master thesis project itself. Most of the graduation projects are done in companies. The master theses are intensively supervised. In these projects, students are required to demonstrate having achieved all of the intended learning outcomes.

Students may be enrolled via EIT Digital in the Embedded Systems track of the master (please refer to section 3.4 for the curriculum of this track). The track is organised by seven Universities in Europe. Students start their first year at one of the universities and continue their second year at one of the other institutions. Upon completion of the programme, they will be awarded the degrees of both universities. The curriculum contents of this track differ to a certain extent from the master programme itself, since 24 EC courses on innovation and entrepreneurship are part of the track curriculum. The technical courses on embedded systems are the same. As in the regular programme, the track ends with the 30 EC graduation project.

The educational principles of the programme focus on interactive teaching, allowing students coming from heterogeneous backgrounds to reach the required level of knowledge and skills in this domain and activating students to take the learning processes into their own hands. The study methods adopted in the programme include lectures, tutorials, exercises, lab sessions and practical assignments. Tele-lectures are adopted in a number of courses, allowing students from other universities to take these courses. Technical problems tend to reduce the effectiveness of this study method. The number of contact hours in the curriculum is 17.7 hours per week in the first year and 7.2 hours per week in the second year.

In the first year, students are guided through the curriculum by their mentor, who advises them on their study paths and informs them about societal and ethical dimensions of embedded systems technology. Guest lecturers touch upon the latter subjects as well. Mentoring is organised across the streams, each of the streams having one mentor and every one of the students having their own mentor. In the second year, study guidance is gradually being taken over by the graduation supervisor. Students expressed being content about the guidance in the programme. Earlier problems regarding the programme scheduling have been resolved, so the students said. The student-to-staff ratio in the programme is 17.6. The success rates of students having completed the programme within three years decreased somewhat from 74 % for the cohort of 2011 to 65 % for the 2012-cohort to 63 % for the cohort of 2013. The success rates of students having completed the programme within two years increased significantly over the past years. So it can be expected that the three year rates will increase as well.

All of the lecturers in the programme are PhD's and are active researchers in their fields of expertise. About 58 % of the lecturers obtained the Dutch University Teaching Qualification (BKO), testifying to their teaching capabilities. Other lecturers (29 %) are exempt of this obligation, on account of their track records in teaching. Following the Eindhoven University of Technology policy, new staff are required to obtain the BKO-certificate. This takes two years. Although about 50 % of the lecturers do not have an English language certificate, language problems do not surface. The students with whom the panel met, were positive about the lecturers.

Considerations
The panel considers the admission requirements and the admission procedures of the programme to be appropriate. The panel welcomes the on-line homologation tool and the on-line homologation courses offered to the students. The panel is also positive about the pre-master programme.

Having studied the diagram presented by programme management, the panel considers the intended learning outcomes to be met in the curriculum. The correspondence of learning outcomes and curriculum components is, however, addressed at a level of rather high aggregation. The panel recommends to draft these relations in a more detailed way, in order to be able to identify more clearly overlap of and gaps between courses from the intended learning outcomes perspective.

The panel regards the curriculum of the programme to be very adequate. The panel is especially positive about the specialisation courses in the four streams which are offered, which are strongly embedded systems-related. The internship requirements are adequate as well. The research knowledge and skills are covered appropriately in the curriculum. Although the panel is positive about the common core courses contents, it is advised to adapt these to offer students a more comprehensive view on the embedded systems domain. The panel considers the EIT Digital Embedded Systems track to be strongly focused on the embedded systems domain and to strengthen the international dimension of the programme.

The panel assesses the educational principles and the study methods of the programme as adequate. They assist students in their learning processes. The panel considers the blended learning activities in the programme to be positive and advises programme management to continue the blended learning projects and experiments in collaboration with the other Universities.

The study guidance in the programme is considered by the panel to be appropriate. The student-to-staff ratio is adequate. The panel welcomes the generous number of hours of face-to-face education in the curriculum.

The panel is very positive about the lecturers in the programme. They are experts in their fields. All of them have PhD's and a substantial number of them possesses BKO-certificates. Being impressed by the comprehensiveness of the University BKO-course, the panel appreciates the University policy, requiring all new staff to obtain the BKO-certificate.

The panel was offered the opportunity to visit some of the laboratories used in the programme. From this inspection and from the description of the facilities by programme management, the panel concludes the facilities to be very good.

Assessment of this standard
These considerations have led the assessment panel to assess standard 2, *Teaching-learning environment*, to be good.

5.3 Standard 3: Assessment

The programme has an adequate assessment system in place.

Findings
The examination and assessment rules and regulations of the programme comply with the Department of Mathematics and Computer Science and the Department of Electrical Engineering assessment policy statements, which in turn correspond to the Eindhoven University of Technology examination framework. The Examination Committee for the programme is responsible for maintaining the examination rules and regulations, for ensuring the quality of the examinations and for the graduates to have achieved the intended learning outcomes.

The examination methods adopted in the courses depend on the nature of the learning goals to be assessed and include written examinations, lab and programming assignments, reports and prototypes. Multiple-choice questions may be part of written examinations but are never the sole method in examinations.

Examinations are drafted by examiners and are peer-reviewed by another examiner. Students are given the right to inspect their examinations. Internship assignments have to be approved by the internship supervisor and internship results are graded by the supervisor. As has been indicated, the graduation project consists of the preparatory phase and the master thesis. The preparatory phase is assessed on the basis of the presentation by the student and the report, problem statement and thesis plan, submitted by the student. The master thesis project is assessed by the thesis assessment committee, consisting of three examiners, one of which comes from another research group. In the case of industry-related projects, a representative of industry may sit on this committee. The thesis committee assesses the project by means of the thesis assessment form, specifying the results of the project, the contents of the report, the process, the presentation and the oral defence.

On behalf of the Examination Committee, the Quality Assurance Committee regularly inspects samples of examinations and samples of master theses. This committee advises the Examination Committee on the comparability of grades across research groups. In addition, the Examination Committee ensures grades for industry-related and research-oriented theses to be comparable as well. The committee explained to the panel the research components in the theses are regarded to be of paramount importance.

Considerations
The panel regards the programme examination and assessment rules and regulations to be adequate, as these comply with assessment policy statements of the departments involved and to meet the Eindhoven University of Technology examination framework.

The responsibilities of the Examination Committee are adequate, since they include monitoring the examinations and assessment procedures, the quality of the examinations and the students' achieving the intended learning outcomes of the programme. The panel especially appreciates the role of the Quality Assurance Committee in regularly inspecting samples of both examinations and master theses.

The examination methods meet the curriculum components' learning goals and are satisfactorily diverse.

The panel considers the examinations and assessments procedures to be appropriate, as these procedures ensure the validity, reliability and transparency thereof satisfactorily. The assessments of the internships are regarded by the panel to be adequate. Although the panel does not doubt the quality of the assessment procedures of the master thesis projects, it is suggested to fill out the thesis assessment forms more elaborately, allowing for more clear substantiation of the sub-grades and the final grade given. In addition, the panel recommends to better align the grading of the master thesis projects conducted in industry and those done in research environments in the University. The panel advises to verify whether industry representatives may be members of the graduation committee.

Assessment of this standard
The considerations have led the assessment panel to assess standard 3, *Assessment*, to be satisfactory.

5.4 Standard 4: Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

Findings
Programme management recorded the grade points average of the graduates of the programme and the grades for the graduation projects for the last two years in order to illustrate the level achieved by the students. The grade point average of the graduates of the programme was 7.3 in recent years. The average grade for the graduation projects is 7.9. About 12 % of the theses led to scientific publications.

Graduates of the programme tend to have generous opportunities on the labour market and find suitable positions rather easily. Nearly all graduates are employed within three months after graduation. Graduates find jobs in the high-tech industry with start-up companies as well as with large, multinational enterprises. Graduates also may pursue academic careers.

The representatives of industry and the members of the External Advisory Board with whom the panel met during the site visit of the University of Twente Master Embedded Systems programme, expressed to be content with the graduates' capabilities.

Considerations
Having studied the examinations of a number of courses of the programme, the panel assessed these examinations to be satisfactory.

The panel reviewed a total of fifteen master theses of graduates of the programme. Having studied these master theses, the panel concluded these to be up-to-standard, meeting the learning outcomes of the programme. None of the theses has been assessed by the panel to be unsatisfactory. Quite a number of theses proved to be good or very good. The panel confirms the relatively high grades given for the theses.

The information provided on the graduates' careers leads the panel to consider the graduates well-prepared for the positions in this field on the academic master level. The alumni careers show that the programme graduates meet the demands of industry as well as those of the academic world. The views expressed by the representatives of industry echo these positive findings.

Assessment of this standard
The considerations have led the assessment panel to assess standard 4, *Achieved learning outcomes*, to be satisfactory.

6. Recommendations

In this report, a number of recommendations have been listed. For the sake of clarity, these have been brought together below. The recommendations are the following.

- To exploit the potential of the programme more fully by further strengthening the collaboration of the programmes of the three Universities of Technology in order, among others, to offer students the range of subjects offered at the three different Universities.
- To draft the relations between the intended learning outcomes and the curriculum components in a more detailed way, to be able to identify more clearly possible overlap of and gaps between courses from the intended learning outcomes perspective.
- To adapt the common core courses in order to offer students a more comprehensive view on the embedded systems domain.
- To continue experiments and projects on blended learning in collaboration with the other Universities, although the initiatives taken by programme management are positive.
- To fill out the thesis assessment forms more elaborately, allowing for more clear substantiation of the sub-grades and final grades given.
- To better align the grading of the master thesis projects conducted in industry and those done in research environments in the University.
- To verify whether industry representatives may be members of the thesis assessment committee.

Annex 1 Site Visit Schedule

The site visit took place in Eindhoven on 27 June 2017. The site visit schedule was as follows.

08.30 h. – 09.20 h. Arrival and deliberations panel (closed session)

09.20 h. – 10.00 h. Dean and programme management, including brief presentation
Prof. dr. ir. A.A. Basten (representative of Dean Department Electrical Engineering),
prof. dr. P.M.E. De Bra (director Computer Science Graduate Programme), prof. dr.
M.G.J. van den Brand (Vice-Dean Department Mathematics and Computer Science), dr.
R.C. van der Drift (managing director Department Mathematics and Computer Science),
prof. dr. J.J. Lukkien (Dean Department Mathematics and Computer Science), dr. S.P.
Luttik (programme manager Embedded Systems)

10.00 h. – 11.15 h. Programme management and core lecturers
Prof. dr. ir. A.A. Basten (coordinator/mentor Cyber-Physical stream), prof. dr. P.M.E. De
Bra (director Computer Science Graduate Programme), prof. dr. J.J. Lukkien (coordinator
Embedded Networking stream). dr. S.P. Luttik (programme manager Embedded
Systems), dr. A. Serebrenik (adjunct-director Computer Science Graduate Programme),
dr. N. Stash (study advisor), dr. ir. S. Stuijk (programme coordinator Embedded Systems)

11.30 h. – 12.15 h. Examination Committee
Dr. ir. R.J. Bril (Examination Committee member), prof. dr. K.G.W. Goossens
(Examination Committee member), prof. dr. ir. J.F. Groote (Examination Committee
chair), dr. E.F. Kaasschieter (Examination Committee external expert member), prof. dr.
ir. J.J. van Wijk (Quality Assurance Committee chair)

12.15 h. – 13.15 h. Lunch panel (closed session), open office hours 12.15 h. – 12.45 h.

13.15 h. – 13.45 h. Tour around facilities

13.45 h. – 14.45 h. Lecturers and thesis' examiners
Prof. dr. ir. C.H. van Berkel (lecturer VLSI Programming), dr. ir. P.J.L. Cuijpers (lecturer
Quantitative Evaluation of Embedded Systems), dr. ir. M.C.W. Geilen (lecturer
Multiprocessors, Embedded Signal Processing Systems, Programme Committee chair),
prof. dr. K.G.W. Goossens (lecturer Embedded Systems Lab), dr. T. Ozcelebi (graduation
projects supervisor), dr. J. Schmaltz (graduation projects supervisor)

14.45 h. – 15.45 h. Students and alumni
S.M.N. Balusubramaniam BSc (student), B. Balmaekers MSc (alumnus, Philips Research,
previously Programme Committee member), T. van Dien BSc (student, Programme
Committee member), ir. J. Redegeld (alumnus, PhD student), J. Rivera Verduzco BSc
(student), M. Zaitsev BSc (student EIT track)

15.45 h. – 17.15 h. Deliberations panel (closed session)

17.15 h. – 17.45 h. Main findings presented by panel chair to programme management

Annex 2 Documents reviewed

The panel studied the following documents, presented prior to the site visit:
- Critical Reflection 4TU Master Embedded Systems
- Subject-specific Frame of Reference Embedded Systems
- Overviews of curricula
- Outline description of curriculum components
- Teaching and examination regulations
- Overview of allocated staff
- Staff qualifications
- List of graduates of the last two years (anonymised)
- Success rates
- Average number of hours of face-to-face instruction

In addition, the panel members were offered additional information on various aspects of the programme.

On the day of the site visit, the programme management presented the following documents:
- Literature
- Course material (representative selection)
- Tests and examinations and assignments (representative selection)
- Examination plan (draft)
- European Institute of Innovation and Technology (EIT) agreements
- Programme Committee minutes
- External Advisory Board minutes
- Examination Committee annual reports
- Evaluation Committee minutes

In addition, the panel members were given access to the programme's electronic learning environment.

Annex 3 Theses reviewed

The theses of the following 15 students have been selected for review by the panel
- 0869737
- 0826982
- 0590864
- 0818215
- 0926183
- 0646831
- 0627940
- 0870886
- 0924737
- 0872664
- 0926459
- 0788600
- 0928200
- 0726604
- 0874452

Annex 4 Assessment panel composition

The assessment panel had the following composition:
- Prof. dr. ir. D.R.M. Stroobandt, full professor Embedded Systems and Hardware Design, Ghent University (panel chair);
- Prof. dr. P. Marwedel, full professor Methods for Computer-aided Design of Integrated Circuits, Dortmund University of Technology (panel member);
- Dr. A.D. Pimentel, associate professor in System and Network Engineering Lab, University of Amsterdam (panel member);
- S. de Vries, general manager of the private company Chess Wise BV (panel member);
- E.E.M. Leo BSc, student Master programme Educational Sciences, University of Amsterdam, (student member).

Prof. dr. ir. D.R.M. Stroobandt (panel chair)
Mr. Stroobandt is full professor Embedded Systems and Hardware Design at Ghent University. He graduated from Ghent University as a Master of Science in Electrical Engineering. Subsequently, he took his doctorate in Electrical Engineering from this University. He has been intensively engaged in scientific research as well as in academic education in his field of expertise. Mr. Stroobandt supervised a range of doctorate theses. He has won several scientific prizes and has published widely in peer-reviewed journals.

Prof. dr. P. Marwedel (panel member)
Mr. Marwedel is full professor Methods for Computer-aided Design of Integrated Circuits at Dortmund University of Technology. He took his doctorate from University of Kiel, Germany. Mr. Marwedel was, among others, member of the Academic Senate of Dortmund University of Technology and Dean of Studies at the Computer Science Department of this University. Mr Marwedel published a wide range of books as well as articles in peer-reviewed journals in his field of expertise.

Dr. A.D. Pimentel (panel member)
Mr. Pimentel is an associate professor in System and Network Engineering Lab at University of Amsterdam. He graduated as a Master of Science in Computer Science and took his doctorate in Computer Science from University of Amsterdam. He was engaged in scientific research in his field of expertise. He undertook numerous academic education activities as a teacher and in educational management. Mr. Pimentel published widely in peer-reviewed journals in this field of expertise.

S. de Vries (panel member)
Mr. De Vries is the general manager of the private company Chess Wise BV. He completed his studies in Electrical Engineering at Leeuwarden Polytechnic. He was subsequently employed by, among others, the companies Manudax and Microproject, working in the Netherlands and abroad. Mr. De Vries proceeded to found the company Chess Wise, a company specialised in wireless lighting management. Mr. De Vries is a non-executive director of Rabobank Haarlem.

E.E.M. Leo BSc (student member)
Ms. Leo is a student in the Master programme Educational Sciences of University of Amsterdam. Previously, she completed the Bachelor programme in Educational Sciences at this University. She was a member of the Educational Committee of her programme and vice-chair of the Student Council of the Faculty of Social and Behavioural Sciences of University of Amsterdam. Ms. Leo participates as a student member on a regular basis in NVAO-accreditation panels.