

Assessment report
Limited Programme Assessment

Master Embedded Systems

Delft University of Technology

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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 Delft 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 introducing three specialisations 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 Delft 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.

The programme admission requirements and admission procedures are adequate. The panel is positive as well about the pre-master programme. Although the homologation courses to remedy deficiencies of students in either computer science or electrical engineering are appropriate for this purpose, the panel welcomes the reduction in credits for these courses, as this will enable students to gain more in-depth knowledge of and skills in the embedded systems domain. The panel supports the intentions of programme management to adopt the on-line homologation tool and to offer homologation courses on-line in order to help accomplishing this reduction. The *Master Kick-Off* introducing the students to the programme, is appreciated by the panel.

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 considers the curriculum of the programme to be quite appropriate. The panel is positive about the core courses and the specialisation courses as well as about the internship requirements and the graduation projects design and appreciates the research knowledge and skills taught in the curriculum. The panel advises, however, to adapt the common core courses to offer students a more comprehensive view on the embedded systems domain.

The educational principles and the study methods of the programme are adequate and assist students in their learning processes. The panel advises 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 as well. The panel regards the student success rates to be satisfactory.

The panel is very positive about the lecturers in the programme. They are experts in their fields and all of them have PhD's. The panel is impressed by the proportion of lecturers having acquired the University BKO-certificate.

The laboratories are definitely up to standard and the study facilities suffice. Given the growth in student numbers, the panel recommends to expand the study facilities for students.

The panel regards the programme examination and assessment rules and regulations to be adequate, these complying with the Faculty of Electrical Engineering, Mathematics and Computer Science assessment policy statements.

The responsibilities of the Board of Examiners are appropriate. They include monitoring the examinations and assessment procedures, the examinations quality and the students' achieving the intended learning outcomes of the programme.

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

The panel considers the examinations and assessments procedures to be good. The examination quality is ensured in the process of drafting the examinations and by the involvement of the Faculty educational expert in that process. The assessments of the internships are adequate. The panel welcomes the elaborate and strict procedures in assessing the graduation projects, as exemplified by the composition of the thesis committee, the use of rubrics scoring forms and the monitoring of these procedures by the Board of Examiners. The panel appreciates the thesis committees' and Board of Examiners' preoccupation with the research dimensions of these projects, especially in the case of industry-related projects. The panel is very positive about the thorough quality awareness regarding examinations and graduation projects, shared by all participants in the examination and assessment processes in the programme.

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 of these 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 Delft University of Technology to be satisfactory and recommends NVAO to grant re-accreditation to this programme.

Rotterdam, 18 September 2017

Prof. dr. ir. D.R.M. Stroobandt
(panel chair)

drs. W. Vercouteren
(panel secretary)

2. Assessment process

Certiked VBI received a request by Delft 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. Vercooteren 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 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 28 June 2017, the panel conducted a site visit at the Delft 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: Computer Architecture, Control Systems, Software & Networking
 Location: Delft
 Mode of study: Full-time (language of instruction: English)
 Registration in CROHO: 60331

Administrative information about the institution:

Name of institution: Delft 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	50 %	53 %	77 %

Lecturers' qualifications

Qualification	MSc	PhD	BKO
Percentage of lecturers	100 %	100 %	87 %

The student-to-staff ratio is 18.2.

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	11.3	2.8

3.2 Main facts about the institution

The Master Embedded Systems programme is a programme of the Faculty of Electrical Engineering, Mathematics and Computer Science of Delft University of Technology.

According to the Delft University of Technology website, the University's mission statement is to make a significant contribution towards a sustainable society for the twenty-first century by conducting ground-breaking and world-class scientific and technological research, by training scientists and engineers with genuine commitment to society and by helping to translate knowledge into technological innovations and activity with both economic and social value. Delft University of Technology wants to remain a technology university with a leading global reputation. To do this, the University's aim is to maintain a full range of high-quality disciplines, courses and unique facilities in the engineering sciences.

Delft University of Technology comprises eight faculties, being the Faculties of Aerospace Engineering, Applied Sciences, Architecture and the Built Environment, Civil Engineering and Geosciences, Electrical Engineering, Mathematics and Computer Science, Industrial Design Engineering, Mechanical, Maritime and Materials Engineering and Technology, Policy and Management. These faculties offer 16 Bachelor programmes and 40 Master programmes. About 21,000 students study at Delft University of Technology and about 5,000 staff are employed by the University.

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 has been presented.

Curriculum components	Credits
Modern Computer Architectures	5 EC
System Validation	5 EC
Quantitative Evaluation of Embedded Systems	5 EC
Real-time Systems	5 EC
Embedded Systems Laboratory	5 EC
Homologation courses	0 - 10 EC
Specialisation courses	25 - 35 EC
First Year	60 EC
Internship/Specialisation courses	15 EC
Specialisation course	5 EC
Graduation Project (literature survey)	10 EC
Graduation Project (thesis project)	30 EC
Second Year	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	Satisfactory
Standard 3: Assessment	Good
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. Due to legal constraints, the three Universities decided, however, not to pursue a joint-degree programme, allowing each of the programmes 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 Delft University of Technology. The panel considers this programme to be internationally a 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 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 Faculty of Electrical Engineering, Mathematics and Computer Science of Delft University of Technology. Management of the programmes of the three Universities meet regularly to discuss the alignment of the programmes. In the months November/December of the first year, students from all three programmes meet in the *Embedded Systems Student Event*. The Delft University of Technology Master Embedded Systems programme is managed by the director of studies. Students and lecturers are represented in the Board of Studies, which counsels the director on quality issues. The joint External Advisory Board of the three Universities advises programme management on the alignment with the professional practice. The Board of Examiners oversees the examinations and assessments of the programme.

The number of students enrolling in the programme increased in recent years, going from the influx of 30 students in 2011 via the influx of 37 students in 2013 to the influx of 60 students in 2015. The proportion of foreign students is substantial, amounting to 60 % to 70 % of the total inflow. 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 to the programme. In case students report deficiencies in either one of these two domains, they are required to take homologation courses to a maximum of 20 EC. Programme management intends to reduce the homologation courses to a maximum of 10 EC, freeing up time for embedded systems-related courses. Students with bachelor degrees in other fields of study or with vocational bachelor degrees should take the pre-master programme of at least 30 EC. Foreign students with these backgrounds, normally, are not admitted, since they will not apply for the pre-master 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. The Faculty of Electrical Engineering, Mathematics and Computer Science Programme management organises the *Master Kick-Off* for students, a three-day event at the start of the programme, in which, among others, research groups present the specialisations offered in the programme.

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. The curriculum consists of common core courses (25 EC), specialisation courses (at least 25 EC), internship (optional, 15 EC) and graduation project (10 EC for preparation phase and 30 EC for thesis project). 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 specialisation courses, students may select one of the specialisations offered, *Computer Architecture*, *Control Systems* and *Software & Networking*. Although the specialisation courses are shared by a number of programmes in Delft, lecturers are requested to tailor their courses to the embedded systems domain. The number of students taking internships has been growing over the years and is now substantial. Internship plans are approved by the supervisor and internship results are assessed.

The graduation projects include the preparation phase, which encompasses a literature study, and the master thesis project itself. About 1/3 of the graduation projects are industry-related, whereas 2/3 are University research-based. The master theses are intensively supervised. In these graduation projects, students are required to demonstrate having achieved all of the intended learning outcomes. Students are not allowed to conduct the graduation project at the internship company. Programme management is considering to introduce entrepreneurial subjects in the curriculum.

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, homework assignments, study of and discussions on journal articles, quizzes and lab assignments. Tele-lectures are used in a number of courses, allowing students from other universities to take these courses. The lack of personal interaction reduces the effectiveness of this study method. The number of contact hours in the curriculum is 11.3 hours per week in the first year and 2.8 hours per week in the second year.

Students are guided through the curriculum by their mentor, who advises them on specialisation courses and their study paths. In addition, students may turn to the study advisor for problems in their study. In lab sessions, students are guided by teaching assistants. Students informed the panel not to experience any problems in finding internships or industry-related graduation projects. The student-to-staff ratio in the programme is 18.2. Students expressed being content about the guidance in the programme. The success rates of students having completed the programme within three years rose from 50 % for the cohort of 2011 to 53 % for the 2012-cohort to 77 % for the cohort of 2013.

All of the lecturers in the programme are PhD's and are active researchers in their fields of expertise. No less than 87 % of the lecturers obtained the Dutch University Teaching Qualification (BKO), testifying to their teaching capabilities. Blended learning is incorporated in the BKO-course. The lecturers meet on a regular basis to discuss teaching on the Faculty or University level. The students with whom the panel met, expressed to appreciate the lecturing on the part of the lecturers.

Considerations

The panel considers the admission requirements and the admission procedures of the programme to be adequate. The panel is positive about the pre-master programme. The homologation courses to remedy deficiencies of students in either computer science or electrical engineering are appropriate for this purpose. The panel, however, welcomes the reduction in credits for these courses, as this will enable students to gain more in-depth knowledge of and skills in the embedded systems domain. The panel supports the intentions of programme management to adopt the on-line homologation tool, being developed in Eindhoven, and to offer homologation courses on-line in order to help accomplishing this reduction. The *Master Kick-Off* introducing the students to the programme, is appreciated by the panel.

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 appreciates the curriculum of the programme. The panel assesses the common core courses to be adequate and the specialisation courses to be appropriately tailored to the embedded systems domain.

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 assesses the educational principles and the study methods of the programme as adequate. They assist students in their learning processes. The panel advises 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 as well. The panel considers the student success rates to be satisfactory.

The panel is very positive about the lecturers in the programme. They are experts in their fields and all of them have PhD's. The panel is impressed by the proportion of lecturers having acquired the University BKO-certificate.

The panel had the opportunity to visit some of the laboratories used in the programme and discussed the facilities with the students. The laboratories are definitely up to standard and the study facilities suffice. Given the growth in student numbers, the panel recommends to expand the study facilities for students.

Assessment of this standard

These considerations have led the assessment panel to assess standard 2, *Teaching-learning environment*, to be satisfactory.

5.3 Standard 3: Assessment

The programme has an adequate assessment system in place.

Findings

The programme examination and assessment rules and regulations comply with the Faculty of Electrical Engineering, Mathematics and Computer Science assessment policy statements. The Board of Examiners for the programme, being one of the sub-committees of the Faculty-wide Board of Examiners, is responsible for maintaining the examination rules and regulations, for ensuring the quality of the examinations and for monitoring 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, among others, written examinations and practical assignments. Academic skills, such as critical thinking and research knowledge and skills are assessed as well.

Examinations drafted by examiners are inspected by the Faculty educational expert and are discussed between the examiner and the expert in order to ensure the quality thereof. The results of the examinations are checked by the Board of Examiners, in case these results deviate from the normal distribution of grades. Internship assignments are approved by the internship supervisor and internship results are graded by the supervisor in terms of pass or fail. The master thesis project is assessed by the thesis committee, which consists of three examiners, one of which comes from another research group. In the case of industry-related projects, a representative of industry may advise this committee. The thesis committee assesses the projects using the thesis assessment form and using the rubrics scoring form to substantiate the grading. The assessment form and the rubrics scoring form address relevant criteria. In case of outlying grades to be expected on the basis of the draft thesis, a Board of Examiners member is present during the student's defence and in the meeting of the thesis committee. The Board of Examiners and the thesis committees give much weight to the research dimensions of the graduation projects, especially in the case of industry-related projects.

Considerations

The panel regards the programme examination and assessment rules and regulations to be adequate, as these comply with the Faculty of Electrical Engineering, Mathematics and Computer Science assessment policy statements.

The responsibilities of the Board of Examiners are appropriate. They include monitoring the examinations and assessment procedures, the examinations quality and the students' achieving the intended learning outcomes of the programme.

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 appropriately. The panel feels the quality of the examinations is very adequately ensured in the process of drafting the examinations and by the involvement of the Faculty educational expert in that process. The assessments of the internships are regarded by the panel to be adequate. The panel welcomes the elaborate and strict procedures in assessing the graduation projects, as exemplified by the composition of the thesis committee, the rubrics scoring forms and the monitoring of these procedures by the Board of Examiners. The panel appreciates the thesis committees' and Board of Examiners' preoccupation with the research dimensions of these projects, especially in the case of industry-related projects.

The panel is especially positive about the thorough and strongly felt quality awareness regarding examinations and graduation projects, shared by all participants in the examination and assessment processes in the programme.

Assessment of this standard

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

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 7.5 in recent years. The average grade for the graduation projects is 8.0. About 24 % 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

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 of these 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.

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 adopt the on-line homologation tool and to offer homologation courses on-line in order to reduce the number of homologation courses' credits in the programme, this in line with programme management intentions.
- 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.
- To expand the study facilities for students in order to prepare for the growth in student numbers.

Annex 1 Site Visit Schedule

The site visit took place at the Delft University of Technology Campus on 28 June 2017. The site visit schedule was as follows.

08.30 h. – 09.00 h.	Arrival and deliberations panel (closed session)
09.00 h. – 09.45 h.	Dean and programme management, including brief presentation Dr. ir. J. Schmitz (Dean of Faculty Electrical Engineering, Mathematics and Computer Science), dr. ir. H. Tonino (director of studies), dr. A. Coetzee (manager Education & Student Affairs), prof. dr. A. van Deursen (head Department Software Technology), prof. dr. ir. H. Hellendoorn (head Department Delft Center for Systems & Control at 3mE)
09.45 h. – 11.00 h.	Programme management and core lecturers Dr. ir. H. Tonino (director of studies), dr. ir. A. van Genderen (master coordinator), dr. J. Caussin (programme coordinator), dr. ir. J. Keiren (lecturer System Validation), dr. ir. S. Wong (lecturer Modern Computer Architecture), prof. dr. K. Langendoen (lecturer Real-time Systems), S. van Aardenne MSc (academic counsellor)
11.15 h. – 12.00 h.	Board of Examiners Prof. dr. ir. A. Heemink (Board of Examiners chair), dr. R.V. Prasad (Board of Examiners member), dr. ir. J. Pouwelse (vice-chair Sub-Committee ES/CS of Board of Examiners), S. Nijemanting MSc (education advisor), T. Termorshuizen MA (Board of Examiners secretary)
12.00 h. – 13.00 h.	Lunch panel (closed session), open office hours 12.00 h. – 12.30 h.
13.00 h. – 13.30 h.	Tour around facilities (various laboratories)
13.30 h. – 14.30 h.	Lecturers and theses' examiners Prof. dr. K. Langendoen (lecturer, Board of Studies chair), dr. M. Zuniga (lecturer), dr. ir. Z. Al-Ars (lecturer, Board of Studies member), dr. ing. J. Kober (lecturer), dr. ir. F. Kuipers (lecturer), dr. ir. R. van Leuken (lecturer, Board of Studies member)
14.30 h. – 15.30 h.	Students and alumni P. Mani (student), Y. Gong (student), D. Verhaert (student, Board of Studies member), L. van Dam (student, Board of Studies member), S. Karger MSc (alumnus), W. Muhammad MSc (alumnus)
15.30 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)
- Examinations and assignments (representative selection)
- Internships
- Throughput internal statistics
- Employers overview
- Thesis assessment form and grading scheme
- Study guide
- Board of Studies annual reports
- External Advisory Board minutes
- Board of Examiners annual reports
- Programme directors 3TU meetings 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

- 4329384
- 4030532
- 4043359
- 1184164
- 4225414
- 4332431
- 4002512
- 1358316
- 4192141
- 4033655
- 4048482
- 4311035
- 4301994
- 4411129
- 1308351

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.