MASTER'S PROGRAMME

MECHANICAL ENGINEERING

FACULTY OF ENGINEERING TECHNOLOGY

UNIVERSITY OF TWENTE

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
E-mail: support@qanu.nl
Internet: www.qanu.nl

Project number: Q0710

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This report was finalized on 26 March 2019.

REPORT ON THE MASTER'S PROGRAMME MECHANICAL ENGINEERING OF THE UNIVERSITY OF TWENTE

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point (September 2016).

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Master's programme Mechanical Engineering

Name of the programme:	Mechanical Engineering
CROHO number:	60439
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	-
Location(s):	Enschede
Mode(s) of study:	full time
Language of instruction:	English
Expiration of accreditation:	31/12/2019

The visit of the assessment panel Mechanical Engineering to the Faculty of Engineering Technology of the University of Twente took place on 10 December 2018.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	University of Twente
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 20 August 2018. The panel that assessed the master's programme Mechanical Engineering consisted of:

- Prof. K.G.S. (Sören) Östlund, professor of Packaging Technology at the Department of Solid Mechanics of the KTH Royal Institute of Technology (Sweden) [chair];
- Prof. H.J. (Henry) Rice, professor in Mechanical Engineering and head of the School of Engineering of Trinity College, Dublin (Ireland);
- Dr. M. (Maddalena) Velonà, coordinator of studies at the Department of Mechanical and Process Engineering (D-MAVT) at Eidgenössische Technische Hochschule (ETH) Zürich (Switzerland);
- Drs. J.J. (Jan) Steen, consultant Quality of Education at Wageningen University & Research;
- Ir. S. (Sytze) Spijksma, groupleader Mechanical & Industrial Design Engineering at DEMCON Advanced Mechatronics B.V.;
- M.M.E. (Maartje) Borst, bachelor's student Mechanical Engineering Eindhoven University fof Technology [student member].

The panel was supported by dr. B.M. (Barbara) van Balen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to master's programme Mechanical Engineering at the Faculty of Engineering Technology of the University of Twente was part of the cluster assessment Mechanical Engineering. In December 2018 the panel assessed eleven programmes at three universities. The following universities participated in this cluster assessment: Delft University of Technology, Eindhoven University of Technology and the University of Twente.

On behalf of the participating universities, quality assurance agency QANU was responsible for logistical support, panel guidance and the production of the reports. Dr. Alexandra Paffen was project coordinator for QANU. Dr. Barbara van Balen acted as secretary in the cluster assessment. She is a certified NVAO secretary.

Panel members
The members of the assessment panel were selected based on their expertise, availability and independence.

Preparation
On 9 December 2018, the panel chair was briefed by QANU on his role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organised on 9 December 2018. During this meeting, the panel members received instruction on the use of the assessment frameworks. The panel also discussed their working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Faculty. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to the University of Twente, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of fifteen theses and their assessment forms for the programmes, based on a provided list of graduates 2016-2018. A variety of topics and tracks and a diversity of examiners were included in the selection. The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to the University of Twente took place on 10 December 2018. During the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

Consistency and calibration
In order to assure the consistency of assessment within the cluster, the following measures were taken:

1. The panel composition ensured regular attendance of (key) panel members, including the chair;
2. The secretary was present at the start of the site visits as well as the panel discussion leading to the preliminary findings at all site visits of Delft University of Technology, Eindhoven University of Technology and the University of Twente.

Report
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project coordinator sent the draft reports to the Faculty in order to have these checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty and University Board.

Definition of judgements standards
In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of both the standards and the programme as a whole.

Generic quality
The quality that, in an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

Unsatisfactory
The programme does not meet the generic quality standard and shows shortcomings with respect to multiple aspects of the standard.

Satisfactory
The programme meets the generic quality standard across its entire spectrum.

Good
The programme systematically surpasses the generic quality standard.

Excellent
The programme systematically well surpasses the generic quality standard and is regarded as an international example.

SUMMARY JUDGEMENT

Standard 1
The master's programme of Mechanical Engineering is offered by the Faculty of Engineering Technology of the University of Twente. Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems and processes that accomplish a desired objective in a safe, ethical and sustainable fashion. Modern mechanical engineering is characterised by increasing multi-disciplinarity, having overlaps with the life sciences, electrical and chemical engineering.

The panel appreciates that the programme integrates fundamental disciplines with practice and theory with engineering tools. The intended learning outcomes are formulated in line with this vision and indicate sufficiently what could be expected from programmes at a master's level. The panel concluded that the intended learning outcomes meet the Dutch qualifications framework and tie in with the international perspective of the requirements set by the professional field and the discipline. It feels, however, that the intended learning outcomes are formulated on a rather general level and could be more specific.

Standard 2
The master's programme has a matrix structure; the student first chooses a competence profile, depending on the type of mechanical engineer he or she would like to become (researcher, designer or manager). Then a choice is made for one of the following specialisations: Biomedical Engineering & Robotics (BE), Design, Production & Management (DPM), Maintenance Engineering & Operations (MEO), Mechanics of Solid, Surfaces & Systems (MS3) or Thermal & Fluid Engineering (TFE). The department has a partnership with Instituto Tecnológico de Aeronáutica (ITA, Brazil) which gives students the possibility to obtain a double degree in Mechanical Engineering & Aeronautics. Students who strive for this specialisation are expected to stay two semesters at each university.

The master's programme has a duration of two years, with the first year dedicated to courses (all 5 EC), while the second year consists of an internship and the graduation project. The main objective of the internship is to put the acquired knowledge and skills into practice in a real professional engineering environment. Students take the lead; they have to choose their own internship and manage their own assignment. Students, staff and the professional field are positive about the position of the internship in the master's programme, but the panel thinks that the added value of the internship in the programme could be better defined.

The structure of the curriculum is clear, and there is a good connection between the research in the department and the specialisations for the master students. The quantity and the quality of the teaching staff are good. The panel likes the direct working relation between staff and students and the open door policy. It appreciates that the management strives to preserve the personal approach to students in the face of growing student numbers.

Standard 3
The programme has an adequate quality assurance system. The assessment policy is very well documented and transparent. There are procedures in place to assure the validity and reliability of the tests. The Examination Board is diligently performing its legal duties and responsibilities. The panel was impressed by its strong involvement in the assurance of the assessment quality.

Standard 4
The panel studied a selection of 15 master's theses and concludes that graduates of the master's programme Mechanical Engineering have achieved the intended learning outcomes. It found the level of the master's theses to be very good and would have graded most theses higher than the graduation committee. The graduates are well prepared for continuing in a PhD programme or a career in industry.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

Master's programme Mechanical Engineering

Standard 1: Intended learning outcomes	satisfactory
Standard 2: Teaching-learning environment	satisfactory
Standard 3: Student assessment	good
Standard 4: Achieved learning outcomes	good
General conclusion	good

The chair, prof. Sören Östlund, and the secretary of the panel, dr. Barbara van Balen, hereby declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 26 March 2019

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK ASSESSMENTS

General remarks cluster Mechanical Engineering

This report constitutes part of the limited programme assessment of the NVAO Assessment cluster Mechanical Engineering representing 11 bachelor and masters programmes in Mechanical Engineering, Automotive Technology, Marine Technology, Offshore and Dredging and Materials Science and Engineering at University of Twente, Eindhoven University of Technology and Delft University of Technology. The findings for each programme are based on the self-evaluations performed by each programme and site visits taking place on December 10-14, 2018.

In the self-evaluation reports and during the site visits, the evaluation panel has encountered many knowledgeable and dedicated programme managers, skilled and engaged teachers, well-educated and enthusiastic students and successful alumni. It is therefore with great pleasure that we can conclude that the overall outcome of the evaluation panel ends on a positive note.

All programmes are based on intended learning outcomes well set in national or international perspective of the requirements currently set by the professional field and the discipline, programme managers, teachers and students work hard to create a motivating and dynamic teaching and learning environment, all programmes have elaborated assessment plans and the achieved learning outcomes are good. Many of the theses read by the evaluation panel are indeed of very high quality, and graduates from the eleven programmes in general have very good career opportunities.

There is of course always room for improvements, and, particularly, the processes around internships, the overall study times and the high dropout rates are areas that should be given continued high attention. The increased internationalisation of the programmes, the growth in number of students and the level of the students are other challenges that needs consideration in the coming years. However, it is the opinion of the assessment panel that the programmes in the Assessment cluster Mechanical Engineering are well prepared to meet these.

On behalf of the Mechanical Engineering Assessment Panel,
Sören Östlund (Chair)

Governance structure of the Faculty

The bachelor's and master's programmes of Mechanical Engineering are embedded in the Faculty of Engineering Technology, one of the five faculties of the University of Twente. The Faculty is managed by the Faculty Board, consisting of the dean, the vice-dean of education, the vice-dean of research, the portfolio holder of operations and a student-assessor. The Mechanical Engineering programmes are managed by a programme director, supported by a bachelor coordinator and a master coordinator. The Faculty of Engineering is organised into five departments: Biomechanical Engineering (BE), Design, Production and Management (DPM), Mechanics of Solids, Surfaces and Systems (MS3), Thermal and Fluid Engineering (TFE) and Civil Engineering (CE). These departments are responsible for research and education. With the exception of the Civil Engineering department, all departments are involved in teaching the Mechanical Engineering programmes. This report concerns the assessment of the bachelor's programme Mechanical Engineering; the assessment of the master's programme is described in a separate report.

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings
Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems and processes that accomplish a desired objective in a safe, ethical and sustainable fashion. Modern mechanical engineering is characterised by increasing multi-disciplinarity, i.e. overlap with the life sciences, electrical and chemical engineering. The collaborating technical universities in the Netherlands as well as ABET[1], OECD[2], and ASME[3] agreed that the overall learning goals of mechanical engineering programmes should cover science (mathematics, physics and thermodynamics), engineering (materials, solid and fluid mechanics, dynamics), and design (specifications, synthesis, modelling and optimisation, manufacturing, evaluation). These requirements necessitate a systems approach in which the various fields of expertise reinforce one another. The department has a partnership with Instituto Tecnológico de Aeronáutica (ITA, Brazil) which gives students the possibility of obtaining a double degree in Mechanical Engineering & Aeronautics.

The intended learning outcomes (ILOs) of the master's programme are organised according to mechanical engineering competences and academic, professional and regulatory competences. The self-evaluation report sufficiently indicated how the level of the ILOs of the master's programme differs from those of the bachelor's programme. Some ILOs of the master's programme are formulated as an advanced variation of the bachelor ILOs. Others are equal, but are applied to more complex theory, problems and contexts in the master's programme.

In the self-evaluation report and during the site visit, the programme management expressed its ambition to integrate fundamental disciplines with practice and theory with engineering tools, which is much appreciated by the panel. The ILOs sufficiently indicate what could be expected from programmes at a master's level. The self-evaluation report described how the programme conducted interviews with professionals in the field to evaluate the ILOs. The results of the alumni survey were also used for this evaluation. The conclusion of this evaluation is that they are still up to date and consistent with the demands of industry. The panel also ascertained that the ILOs meet the internationally accepted description for academic master's programmes, the Dublin descriptors, which are elaborated for the engineering programmes in the 4TU (Meijers) criteria[4]. The ILOs are also in line with the ABET, OECD and ASME requirements. However, the panel thinks that they are formulated on a rather general level, and give limited information about the domain. The panel recommends specifying them for the mechanical engineering programme.

The programme has an Industrial Advisory Board consisting of representatives from industry (e.g. Apollo Tyres, Philips, Tata Steel, Thales and Demcon). This Board meets with representatives from the mechanical engineering programmes twice a year to exchange ideas and give advice on educational as well as research-related matters.

Considerations
The panel concluded that the ILOs meet the Dutch qualifications framework. They sufficiently indicate an academic master's level. The alignment with the ABET, OECD and ASME requirements demonstrates that they tie in with the international perspective of the requirements set by the professional field and the discipline.

The panel thinks that the ILOs could be made more specific to the domain of mechanical engineering; thus, they would give even more direction to the construction of the courses and the curriculum. They are specific enough to fulfil the requirements for standard 1, though.

[1] ABET – Criteria for accrediting engineering programs
[2] OECD – A tuning –HELO conceptual framework of expected/desired learning outcomes in engineering
[3] ASME – An Environmental Scan for ASME and the Global Summit on the Future of Mechanical Engineering.
[4] https://www.ram.ewi.utwente.nl/embedded2017/doc/Meijers_summarised.pdf

Conclusion
Master's programme Mechanical Engineering: the panel assesses Standard 1 as satisfactory.

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings
The master's programme has a matrix structure; the student first chooses a competence profile, depending on the type of mechanical engineer he or she would like to become. Then a choice is made for one of the five specialisations. The three competence profiles are:
- Research & Development (researcher)
- Design & Construction (designer)
- Organisation & Management (manager)

The specialisations offered are:
- Biomedical Engineering & Robotics (BE)
- Design, Production & Management (DPM)
- Maintenance Engineering & Operations (MEO)
- Mechanics of Solid, Surfaces & Systems (MS3)
- Thermal & Fluid Engineering (TFE)

The department has a partnership with Instituto Tecnológico de Aeronáutica (ITA, Brazil), which gives students the possibility of obtaining a double degree in Mechanical Engineering & Aeronautics. Students who strive for this specialisation are expected to stay two semesters at each university.

The master's programme has a duration of two years, with the first year dedicated to courses, while the second year consists of an internship and an individual graduation project. All courses are 5 EC each. The main objective of the internship is to put the acquired knowledge and skills into practice in a real professional engineering environment. The graduation project can be carried out internally or externally, but always takes place under the supervision and responsibility of one of the research groups within the Faculty.

The master's programme is oriented to the individual student creating his or her own unique signature by the selection of a profile combined with a specialisation in a content area. Research is an integral part of many courses throughout the programme. The overall teaching concept used in the programme is Student-Driven Learning (SDL). This approach is reflected in the interactive teaching methods during lectures and tutorials and the increasing self-responsibility for one's own learning process. The panel had some questions about the matrix structure of the master's programme and the purpose of the profiles in this matrix. It was concerned that these profiles might be too restrictive. The students and teachers convinced the panel, however, that the profiles gave them focus at the start of the master's programme but did not restrict them to a certain role. For instance, an initial choice for the profile design & construction would not prevent the students from going for a PhD trajectory after graduation.

An important part of the second year is the internship. The internship is specifically aimed at giving students the opportunity to become acquainted with one particular company and experience what it is like to be working in a company setting as part of a team of professionals. An important aspect of the internship is also that students are steering it: they have to choose their own internship and manage their own assignment at the internship. This is considered an important learning experience for them. There is an internship coordinator in the programme and a list of companies that offer internships; the students can also ask the teachers to help them get contacts. The students and teaching staff confirmed that this system does work. The panel did not get a clear picture of how the

internship adds to the ILOs, however, and how the quality of the internship is assured. It advises developing clear criteria for the selection and assessment of the internship.

Students and study progress
The number of incoming students in the master's programme is rising steadily from 32 in 2008 to 190 in 2014, of which around 20% is international. Although the duration of the programme is 24 months, students take on average 28 months to finish it. The panel considers this an acceptable average duration. The students report that the study load in the master's programme is high but manageable. When delay occurs, this is usually during the finishing of the master's thesis. Students decide to take more time for the project to achieve a more positive result of their research or aim for a higher mark. The panel advises limiting the possibilities to extend the master's thesis phase for those reasons. Students should also learn that not all research projects have positive results. Higher marks should, in the panel's opinion, be positively weighted for theses that are finished within the scheduled time.

During the site visit the panel discussed the challenges of the increased intake of international students in the master's programme with both teachers and students. The programme coordinator informed the panel that it is hard to make an early estimation of the number of incoming master students. A huge number of international students apply, but many do not meet the requirements. Furthermore, a percentage of the accepted students chooses another university in the end. The teaching staff sees some difference in knowledge and skills between the Dutch students and the international students. This is confirmed by the students. Mostly the learning style and attitude towards the teachers differ, but this doesn't lead to any major problems. On the contrary, the cultural differences are valued as adding to the learning experiences of all students and their competences to work in teams with different disciplinary and cultural backgrounds.

Teaching staff
Most of the programme is taught by the scientific staff of the Faculty of Engineering Technology. The mathematics courses are given by lecturers of the Faculty of Electrical Engineering. All lecturers are required to successfully complete the University Teaching Qualification (UTQ), and 83% of the staff has already obtained this qualification, while the rest of the staff is working on it. Of the lecturers, 88% has a PhD degree and is involved in both teaching and research. The panel likes the small scale, the direct working relation between staff and students and the open door policy of staff, which was lauded by both staff and students during the site visit. The programme management confirmed that the personal approach is a unique feature of the Twente programme, and one they want to maintain despite the increasing student numbers. The panel thinks that this will increase the workload of the teaching staff, although the programme management has taken several measures to cope with the student numbers, including recruiting new teaching staff, appointing an extra study advisor and renting new offices. According to the programme management there are sufficient financial resources to recruit new staff, but the market for recruitment is tight. The panel supports the plans of the Faculty management to improve the gender balance in recruitment, as it noted that there is room to improve the gender diversity in the teaching staff. Mechanical Engineering is still a male-dominated programme, and the percentage of female students is also quite low at 10%.

The students are positive about the teaching skills of the staff and very pleased with the close contacts and the open door policy. Overall, the panel thinks that the quality of the teaching staff is good, and it appreciates that the management wants to preserve the personal approach to students, despite growing student numbers. It recommends monitoring the potentially increased workload of the teaching staff as a result.

Considerations
The curriculum of the master's programme Mechanical Engineering enables the students to achieve the intended learning outcomes, according to the panel. The structure of the curriculum is clear, and there is a good connection between the research in the department and the specialisations for the master students. Students are stimulated to create their individual study trajectory, and the panel is

convinced that the matrix with the profiles generally supports the students in their choices. The study load of the master's programme is high, mainly because of the amount of specialised knowledge the students have to acquire, but students report that they are comfortable with this. The panel finds the curriculum to be good and comparable to the curricula of other engineering master's programmes. Students, staff and the professional field are positive about the position of the internship in the master's programme, but the panel thinks that the added value of the internship in the programme could be better defined.

The quantity and the quality of the teaching staff are good. The panel likes the direct working relation between staff and students and the open door policy. It appreciates that the management wants to preserve the personal approach to students, despite growing student numbers. It recommends monitoring the increasing workload of the teaching staff. It also supports the Faculty's policy to attract more female teaching staff.

Conclusion
Master's programme Mechanical Engineering: the panel assesses Standard 2 as satisfactory.

Standard 3: Student assessment
The programme has an adequate system of student assessment in place.

Findings
Student assessment
A variety of assessment methods is used in the master's programme, such as assignments, exams with open questions and multiple-choice questions, presentations and oral exams. This ensures that the knowledge, skills, attitudes and more complex behavioural competences are assessed. Most courses use a combination of assessment methods. Information about the examinations and the assessments is described in assessment plans. The assessment of the internship is based on a report prepared by the student and containing a content-related part and a reflection on learning experiences gained during the internship. It was not clear to the panel how the quality of the assessment of the internship is assured. It thinks that there should be more control over the quality of the internship and the alignment of the internship with the ILOs. It endorses the measure taken for 2018-2019 that the internship report will be assessed by the master's thesis supervisor using a list of assessment criteria. It encourages the programme to develop clear criteria for the quality of the internship position to be sure that all students can achieve the ILOs for this part of the master's programme.

The master's programme is concluded by the master's thesis. This can be either a research or a more design-oriented project, depending on the student's chosen profile. At the end of the project, a report or paper is delivered and presented during a graduation colloquium, consisting of a presentation and a one-hour oral examination. The master's thesis is assessed by a graduation committee consisting of three assessors, the professor of the research chair, the master's thesis supervisor and one assessor from a different research chair, and making use of a clear assessment form.

Assessment policy
Quality assurance of the assessments takes place according to the assessment policy document. This document describes how the Plan-Do-Check-Act cycle is followed to assure assessment quality. This policy describes that an assessment plan has to be drawn up for each course, all exams should have answer models and scoring forms, and course assessments should be evaluated. The results of these evaluations are followed up. The panel has seen the documents and assessment plans and finds them to be very well documented. During the site visit the panel checked whether the assessment policy and plans worked in practice and was convinced that they do.

Examination board
The Examination Board has the legal task to ensure the quality of the examinations and thesis assessment. It performs this task by ensuring that every test or examination is checked by a peer lecturer. Afterwards the tests are subject to statistical analysis. The Board safeguards the relation between the learning outcomes of courses, the education methods and assessment methods, draws up guidelines for extra resits and the temporal validity of separate module components, investigates cases of suspected fraud/cheating, determines and sanctions fraud cases, appoints examiners and advises about the EER (Education and Examination Regulations) and the pass/fail regulation for the BSc modules.

The panel had a meeting with the Examination Board during the site visit and learnt that the Board also checks assessment dossiers and aims to continuously improve the methods to perform these screenings. The screenings often lead to recommendations to the programme management and the teaching staff. The panel was impressed by the strong involvement of the Board in the assurance of the assessment quality.

Considerations
The panel established that the master's programme Mechanical Engineering has a good quality assurance system. It finds the assessment policy to be very well documented and transparent. There are procedures in place to assure the validity and reliability of the tests. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable. It also established that there are assessment forms in place. It has some questions, however, concerning the assessment and quality assurance of the internships and advises the programme to develop clear criteria for the selection of internship positions in order to be sure that all students can achieve the intended learning outcomes for this part of the master's programme.

The panel established that the Examination Board is performing its legal duties and responsibilities in a very profound way and was impressed by its strong involvement in the assurance of the assessment quality.

Conclusion
Master's programme Mechanical Engineering: the panel assesses Standard 3 as good.

Standard 4: Achieved learning outcomes
The programme demonstrates that the intended learning outcomes are achieved.

Findings
The panel studied a selection of 15 master's theses to assess whether the graduates had achieved the ILOs. It concluded that the graduates did indeed achieve the level that can be expected of them. It studied a selection with a mix of high grades and low grades and found them to be of a high level overall. It would have graded most theses higher than the graduation committee but was reassured by the spread of marks awarded. The theses showed that the graduates have an advanced level of knowledge in a specialised field, systematic understanding of the key aspects and concepts in mechanical engineering, and the ability to integrate theory and practice. The studied theses demonstrated good mastery of scientific theory, design and research skills.

To determine whether the level of the master's programme meets the expectations of the professional field, the programme management interviewed different organisations employing its alumni, and it made use of the results of the National Alumni Survey for information about the level achieved by graduates. The panel had access to the survey reports. The alumni are very positive about the programme. They have found jobs easily, mostly in a field related to mechanical engineering. The employers spoke favourably about the graduates. Organisations are very satisfied with the alumni; they fit very well into their organisation, and they would recommend the alumni to

others. The alumni of the master's programme are well prepared for either a PhD programme or industry and are highly appreciated by the industry for their skills and knowledge.

Considerations
The panel concludes that graduates of the master's programme Mechanical Engineering have achieved the intended learning outcomes. It found the level of the master's theses to be very good and would have graded most theses higher than the graduation committee. The graduates are well prepared for continuing in a PhD programme or a career in industry.

Conclusion
Master's programme Mechanical Engineering: the panel assesses Standard 4 as good.

GENERAL CONCLUSION

The panel assesses standards 1 and 2 as satisfactory and standards 3 and 4 as good. It was very positive about the assessment system and the level achieved by the graduates. Following the NVAO decision rules, the panel's general conclusion is that the programme is assessed as good.

Conclusion
The panel assesses the *master's programme Mechanical Engineering* as good.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Introduction
Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems and processes that accomplish a desired objective in a safe, ethical and sustainable fashion. Mechanical engineers therefore improve the quality of life, address societal challenges, and improve industrial competitiveness. No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways. There is great variety in fields of application: from small to large scale, static and dynamic, from deep-sea to space, to name a few. Modern mechanical engineering is characterized by increasing multidisciplinarity, i.e. overlap with life sciences, electrical and chemical engineering etc. This necessitates a systems approach in which the various fields of expertise reinforce one another, giving rise to world leading mechatronics, nanomanufacturing, robotics, precision agriculture, shipbuilding and more. The Netherlands stands out in this respect, which, along with a strong entrepreneurial spirit, partly explains its innovative power.

Curriculum
Between the technical universities, active collaboration and exchange of students and faculty takes place. The three curricula in Mechanical Engineering in the Netherlands, at Delft University of Technology, Eindhoven University of Technology and University of Twente, comply with the definitions in ABET, OECD and ASME. The curriculum is based on a solid scientific foundation, deep engineering knowledge, and agile engineering design skills. A variety of modalities is used, such as courses and projects, designed to mutually stimulate each other; i.e. the knowledge from the courses is to be applied in the projects, and conversely, in their design projects students will experience the need for and utility of basic knowledge and engineering methodology.
Overall learning goals cover science (mathematics, physics and thermodynamics), engineering (materials, solid and fluid mechanics, dynamics), and design (specifications, synthesis, modelling and optimization, manufacturing, evaluation).

The Bachelor curriculum is composed of three key components:
1. Basic science (mathematics, physics, thermodynamics)
2. Engineering courses (solid and fluid mechanics, dynamics, and control)
3. Design projects (integration of the above analysis tools in a synthesis-oriented group effort, along with dedicated knowledge acquisition and soft skill training). Projects are structured accordingly, with integration of design specification, synthesis, modelling and optimization, manufacturing, evaluation and presentation techniques.

The Bachelor includes a one-semester Minor of choice or elective programme plus a Bachelor end project, i.e. a research or design project performed in small groups or individually.

The Master curriculum is composed of one year of courses in a MSc track, plus a second year of internship (optional in some cases) and graduation project including a literature study, in which students mature to independent engineers or researchers. In some cases (part of) a graduation study is done in a company or another lab (abroad). In several cases a graduation study results in a scientific publication.

Criteria for a Mechanical Engineering programme
The engineering field requires an understanding of core concepts including solid and fluid kinematics, thermodynamics, control, materials science, and structural analysis. Mechanical engineers use these core principles along with tools like computer-aided engineering and product lifecycle management to design and analyse manufacturing plants, industrial equipment and machinery, heating and cooling systems, transport systems, aircraft, watercraft, robotics, medical devices and more. The field has continually evolved to incorporate advancements in technology, and mechanical engineers

today are pursuing developments in such fields as composites, mechatronics, additive and intelligent manufacturing and nanotechnology.

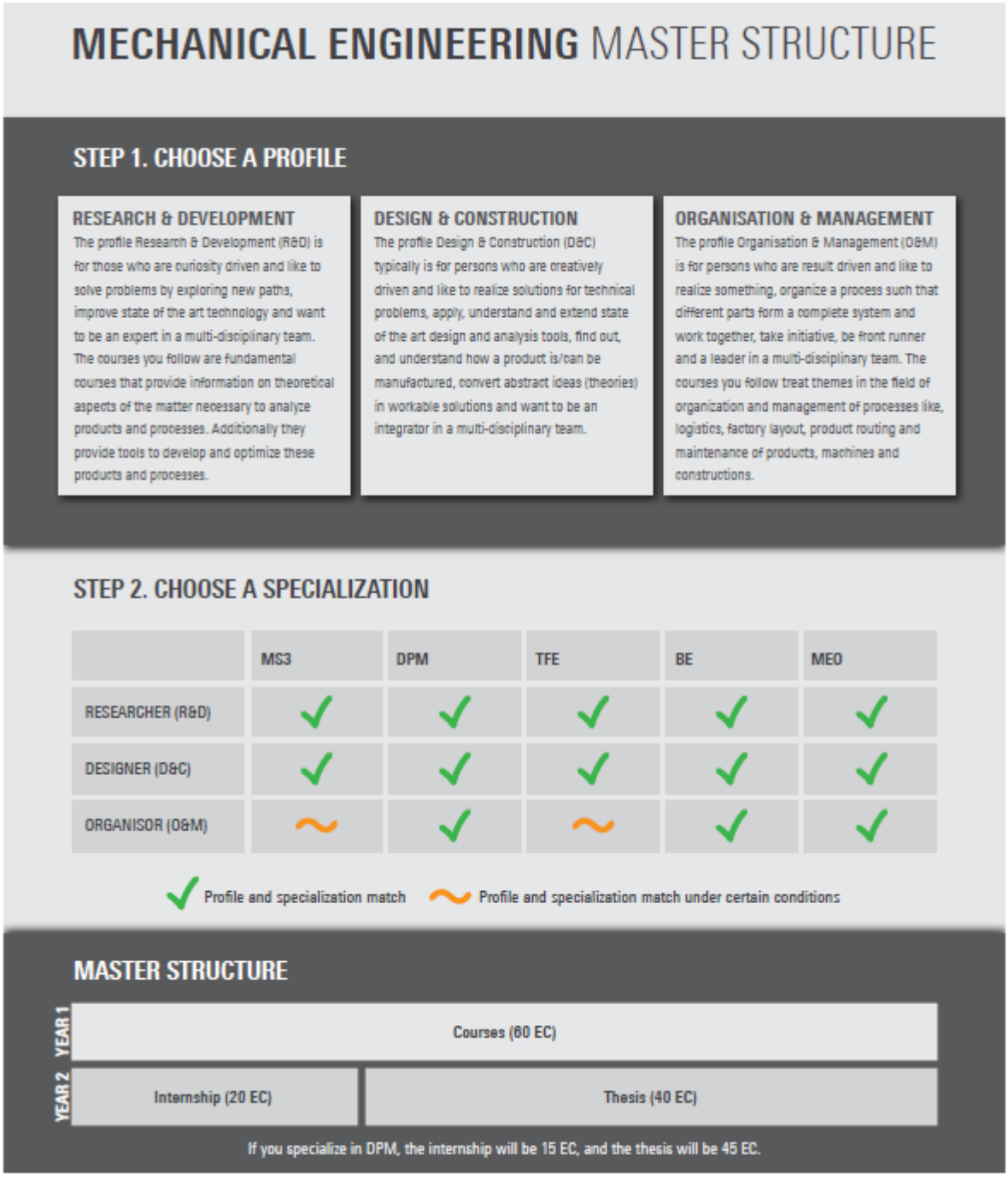
The fundamental subjects of mechanical engineering include:
- Statics and dynamics
- Solid mechanics and strength of materials
- Materials engineering
- Mathematics including calculus, differential equations and linear algebra
- Thermodynamics, heat transfer, energy conversion
- Fluid mechanics and dynamics
- Mechanism design (including kinematics and dynamics)
- Manufacturing engineering (technology and processes)
- Design engineering (including CAD/CAM)

Mechanical engineers are also expected to understand and be able to apply basic concepts from chemistry, physics, chemical engineering, civil engineering and electrical engineering. Most mechanical engineering programmes include multiple semesters of calculus, as well as advanced mathematical concepts including differential equations, partial differential equations, linear algebra, abstract algebra, and differential geometry, among others.

The domain specific requirements are translated into intended learning outcomes of the programme.

BSc	MSc	DSRF
Mechanical engineering competences at academic level		
a. Comprehensive and thorough technical and scientific knowledge of the various fields of mechanical engineering (mechanics, fluid mechanics, heat transfer, energy, systems and control, dynamic systems, design and construction) and the skills to use this knowledge effectively.	a+. Advanced level of knowledge within at least one sub discipline and the ability to apply this knowledge in design and research in this area.	Basis and Engineering Sciences
b. Thorough knowledge of methods, paradigms and tools to analyse and interpret data.	b+. Ability to design and conduct experiments, to develop models and simulations.	Engineering Practice
c. The ability to contribute to the solution of technological problems using a systematic approach that includes analysis, the formulation of sub problems and the evaluation of the implementation.	c+. Ability to identify, formulate and solve engineering problems by designing and developing innovative solutions, including evaluating the feasibility.	Engineering Analysis
d. The ability to integrate theory and practice from various sub disciplines.		Basis and Engineering Sciences
e. The ability to apply techniques, skills and modern "engineering tools" when these are relevant to the engineer's practice.		Engineering Practice
f. The ability to design a system, component or process that meets the set requirements and prerequisites.		Engineering Design
Academic, professional and regulating competences		
g. The ability to effectively communicate with professionals about one's own work and its relevance and impact in various contexts.		Generic Skills
h. The ability to operate as part of a (interdisciplinary and/or international) team, to take initiative, and to recognise and fill gaps in one's knowledge.	h+. Ability to work independently on a design or research assignment	Generic Skills
i. The ability and attitude to evaluate the impact of one's own work from a technological, social and ethical perspective and take professional responsibility for one's decisions.	i+. Insight in the complex working of modern industrial organisations	Generic Skills
j. The ability to continue one's education in a subsequent master programme.	j+. Ability to decide about the first step in one's professional career	Generic Skills
k. The attitude and ability to maintain and continuously improve one's academic and professional skills (life-long learning).		Generic Skills

APPENDIX 3: OVERVIEW OF THE CURRICULUM



The first year of the MSc programme is dedicated to courses, whereas the second year consists of an internship and graduation project. All master courses are 5 EC.

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Monday 10 December 2018

Time	Activity	Participants / remarks
8.30 - 9.00 hrs.	Arrival, welcome, studying course material (reading table)	
9.00 - 9.45 hrs.	Programme management (incl short presentation)	Programme director, Bachelor Coordinator, Master Coordinator, Study adviser Bachelor, Study adviser Master
9.45 - 9.50 hrs.	Panel deliberation	
9.50 - 10.30 hrs.	Bachelor Students	Two first year students, two second year students, two third year students
10.30 - 11.15 hrs.	Master Students & Alumni	Six master students and two alumni
11:15 - 11.30 hrs.	Panel deliberation	
11.30 - 12.30 hrs.	Staff Bachelor and Master	
12.30 - 13.30 hrs.	Panel deliberation, and warm lunch	
13.30 - 14.00 hrs.	Programme Committee	
14.00 - 14.30 hrs.	Examination Board	
14.30 - 15.00 hrs.	Panel deliberation	
15.00 - 15.45 hrs.	Formal management	Dean Engineering Technology and Vice Dean Education
15.45 - 17.15 hrs.	Drafting preliminary conclusions	
17.15 - 17.30 hrs.	Oral feedback from chair	

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the master's programme Mechanical Engineering. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Education and Exam Regulations Bachelor and Master programme
- Reports Industrial Advisory Board
- SDL Brochure
- Survey Professional Field
- Alumni Survey
- Benchmark Mechanical Engineering
- TOM brochure
- Module Assessment Plans Bachelor programme ME
- Module Assessment Plans Master programme ME
- Annual Report Examination Board 2016-2017, 2017-2018