Final Assessment Report
Mechanical Engineering
(GDip/MASc/MEng/PhD)
June 2016

Summary of the Program Review:

In accordance with the University Institutional Quality Assurance Process (IQAP), this final assessment report provides a synthesis of the external evaluation and the internal response of the graduate programs (MEng, MASc, PhD) in Mechanical Engineering. A self-study report (Volume I) was submitted to the Associate Provost, Graduate Studies Office in August 2014. The self-study presented the program descriptions and learning outcomes, an analytical assessment of the three graduate programs, and program data including the data collected from a student survey along with the standard data package prepared by the Office of Institutional Analysis & Planning (IAP). Appended were the course outlines for all courses in the program and the CVs (Volume II) for each full-time faculty member in the Department.

Two arm's-length external reviewers, Dr. Zouman Dong, Professor & Chair, Department of Mechanical Engineering, University of Victoria and Dr. Patrick Oosthuizen, Professor Emeritus, Department of Mechanical & Materials Engineering, Queen's University, were selected by the Associate Provost, Graduate Studies, from a list of arm's length reviewers provided by the department (Volume III). The Associate Provost, Graduate Studies, also selected the internal member of the review team, Dr. Peter Hall, Associ ate Professor, Department of Kinesiology.

The review team reviewed the self-study documentation and conducted a site visit at the University of Waterloo on January 28 & 29, 2015. The visit included interviews with the Vice President & Provost, Associate Provost, Graduate Studies, the Dean and Associate Dean, Graduate Studies, for the Faculty of Engineering, Chair and Associate Chair, Graduate Studies, of the department, faculty members, administrative and technical staff and a group of 25 current graduate students and support staff. The review team also had an opportunity to visit eight research laboratories covering the five major academic areas in the department: Automation & Controls, Fluid Mechanics, Materials Engineering & Processing, Solid Body Mechanics & Mechanical Design and Thermal Engineering.

Program characteristics:

The MME graduate programs last were reviewed in 2007 and classified as "Good Quality". The MME graduate program has continued its growth in the last seven years, and today it is one of the largest graduate programs in North America. The department continues to focus research efforts around five major fields of Mechanical and Mechatronics Engineering as follows: 1) Automation and Controls (A&C), 2) Fluid Mechanics (FM), 3) Materials Engineering & Processing (MEP), 4) Solid-body Mechanics & Mechanical Design (SMMD) and 5) Thermal Engineering (TE).

The MME Department offers MEng, MASc, and PhD programs, as well as 3 type II graduate diplomas. The department also participates in the collaborative PhD and MASc programs in Nanotechnology, along with other departments in Faculty of Engineering and Science. Within the MEng program, the department offers type II graduate diplomas in Green Energy, Design and Fire Safety; the three diploma programs were approved in 2012.

MEng.

The MEng program aims to provide greater breath of understanding of engineering principles and recent technology arising from engineering research to solve problems in industry. This objective is achieved through courses only; a thesis is not required. The MEng program is enhanced by three type II graduate diplomas, which can be completed in parallel with the MEng degree by electing specified courses. The graduate diplomas aim to provide students with greater depth of expertise in the areas of Green Energy, Design and Fire Safety.

MASc.

The MASc program aims to provide a deeper understanding of the theoretical principles and analytical methods necessary to permit effective cutting edge research and development. The MASc provides a foundation in advanced engineering research for those who wish to pursue a PhD. This objective is achieved mainly through courses and a thesis requirement. The MASc also prepares graduates to function as highly-skilled engineers in industry, giving them the capability to effectively use the literature, to conduct complex long term projects and to direct large engineering projects that have a significant research component.

PhD.

The PhD program aims to provide the required theoretical and experimental knowledge and research methodology to conduct cutting-edge independent and original research. This objective is achieved through courses, a comprehensive examination and a thesis requirement. The PhD prepares graduates for careers in academia, industrial and government research centres, and entrepreneurship.

Summary of strengths, challenges and weaknesses based on self-study:

Strengths

- University of Waterloo has the largest MME program in Canada and is home to nearly 2000 undergraduates, graduate students, faculty and staff
- The MME graduate program at Waterloo is one of the strongest in terms of graduate student enrollment in Canada
- MME has secured close to $129M of research funds since 2007
- These research funds have provided for the creation of excellent research facilities (some of which are unique in Canada and even North America) and provide a research environment conducive to excellence
- MME has achieved an international reputation for its research activities and its graduate/undergraduate programs and attracts excellent students from all over Canada and the world

Challenges

- Finding methods for reducing the financial burden on supervisors in recruiting graduate students
- Not having enough space to accommodate all graduate students, PDF's and visiting scholars and the poor quality of some graduate offices
- Ways to increase constructive interactions among their graduate students

Weaknesses

- MME currently has 9 (17.3%) female faculty members out of a complement of 52 faculty

Summary of key findings from the external reviewers:

The report of the review team was very positive. They found that the *"MME graduate program is of very high quality and is providing an excellent educational experience to students enrolled in the four graduate degree and diploma programs"* They further noted *"Since the last academic program review in 2007, the program has made substantial progress in both the quality and scope of the research program and the infrastructure that facilitates world-class graduate learning and research"*.

"Overall, the MME graduate program and department are running smoothly and have been continuing to strive for excellence in every aspect. The Department continuously enjoys high national and international reputation in research and education. Faculty, support staff and students are enthusiastic, devoted, and collegial. The continuous success of the MME program can be credited to the strong and visionary leadership of the Graduate Program, the MME Department, and the Faculties of Engineering and Graduate Studies, the collective effort of very competent and passionate faculties, as well as the effective open and inclusive management structure (or the distributed decision making process)".

There are a few areas in the program that the department needs to consider modifying or improving … but these involve only a small portion of the program and do not negate the conclusion that the program is of very high quality. Among these, an alternative space expansion plan in case the construction of the new E7 building is delayed is relatively important.

"The review committee has noticed that a plan for continued improvement of research and graduate student working space is unfolding over the next two years, and the committee strongly encourage full implementation of the plan developed by the MME Department and Faculty of Engineering to ensure continued success of the excellent graduate program and the planned expansion of the undergraduate programs at MME".

Program response to external reviewer recommendations:

The review committee offered recommendations on specific aspects of the program and its operation that fall into three categories:

1) Space issues
2) Recommendations that will require minor changes to the programs
3) Recommendations that may lead to major changes in the programs

Space

1) The review committee expressed the opinion that the quality and quantity of some graduate space and certain research labs was sub-standard. This finding was in line with the Self-Study report on the poor quality of some graduate offices and not having enough space to accommodate all graduate students, PDF's and visiting scholars. The external assessors suggested that since *"the construction of E7 largely relies on the university receiving funding from the provincial government it may be wise to do some contingency planning in the event that the building does not become available as soon as originally anticipated"*.

   Our contingency plan is the scheduled provision in October 2015 of ~1400 NASM in EC4. This space includes 27 faculty and research offices, open-plan carrel seating for 86 graduate students, and several research labs and a seminar room. This is expected to address the current space issues and to accommodate new faculty and graduate students, and allow the existing sub-standard space to be renovated and reconfigured. E7 will provide the additional lab and office space required to accommodate the new faculty and graduate students as the department reaches steady state in 2021 and beyond.

Recommendations that will require minor changes to the programs

2) The review committee offered the following recommendations that the MME Dept. believes would need minor changes to our current programs. These are:

   - *"The time to completion for MASc and PhD degrees in MME is slightly longer than the set targets. A number of graduate students remain in their program beyond the duration of government support to the university. The present department policies and reward mechanism are encouraging degree completion on time, <u>while additional efforts may be made to address the special issues of the students with timely completion challenges</u>"*.

     MME plans: Completions by Academic Year for MEng students in the past seven years (2007-2014) is 1.6 (the same as Faculty average); for MASc this is 2.4 (the Faculty average is 2.3) and for PhD is 4.4 (Faculty average is 4.6). To reduce the time to completion for MASc and PhD degrees to set targets, the MME Graduate Studies Office (GSO) will monitor the progress of its graduate students through Student Activity Reports (SAR), and proactively inform students of their interim time limits (e.g.,

comprehensive exam time limit). In the cases of low SAR progress evaluation, the graduate associate chair will meet with the student and their supervisor(s) to review the circumstances leading to the underperformance of the student. The student will then be asked to submit a plan/timeline to graduation. The Department will more actively pursue completion of the comprehensive exam by the end of fourth term by requesting an extension request beyond term four. The importance of meeting program completion targets was discussed with faculty, as they are the best immediate monitors of student progress, in June 22, 2015 department meeting.

- *"It appears that many MEng students would like to know what the graduate course offerings will be in the three year period following their first registration. This would allow them to better plan their course selections"*.

  Due to the program expansions at the undergraduate level and the associated hiring of new faculty planned over a 7-year period, MME has not been able to project its graduate and undergraduate teaching schedules for much more than one year ahead, and in some cases, schedule changes have had to be made a few months before the start of term. As such, providing a 3-year graduate teaching schedule before the department reaches steady state in 2018 will be difficult. However, MME is currently targeting one-year advance scheduling for graduate courses. Since fall 2016 the department is providing a list of core graduate courses and their routine yearly offering sequence for all graduate students. The list includes 20 graduate courses.

- *"Graduate students undertaking experimental research should be encouraged to obtain more help from the staff in the departmental machine/workshop and from the Lab technician"*.

  This comment was discussed at the Department meeting to ask supervisors to encourage their grads to seek more help from staff and technicians. The Department has recently revised the technical staff reporting structure to facilitate research assistance, and has also created an on-line list of the expertise of each technical staff member, available to graduate students through the MME grad studies website.

- *"The department should probably continue to offer a workshop for newly enrolled students seeking a Teaching Assistantship"*.

  Besides the ExpecTAtion workshop run by the Faculty, the MME department with the help of CTE has arranged a focused workshop on 'successful TAing of ME courses'. The workshop is open to all MME grad students including newly enrolled students.

- *"In the meeting with graduate students the view was expressed that when there were a significant number of MEng students in a 600 or 700 level course that was also being taken by MASc and/or PhD students the instructor often found it to be necessary, in order to meet the needs of the MEng students, to simplify the lecture materials and to cover background material that was well-known and understood by the MASc and PhD students with stronger academic backgrounds. As a result of this the course descriptions often failed to describe what was actually being taught in the courses and the courses themselves were often at a level that was below that needed by the MASc and PhD students. Many students felt that the listed prerequisites for 600 and 700 level courses needed to be more rigorously applied and that more courses intended purely for MEng students needed to be offered. It was also noted that having more courses intended purely for MEng students would allow these courses to be offered in the evening which would make it easier for many of the MEng students who had full-time jobs to take them. Expansion of the MEng program and enrollment may help to solve this problem."*

  The Department is offering a total of 10 graduate courses that are mainly for MEng students (also open to other graduates). These courses are all in association with our graduate diplomas that are offered within our MEng program. In the past, a course was developed beyond the GDip's programs and offered in the popular area of Finite Elements for the MEng students. However, due to a lack of resources, further offerings of this course was not possible. With current teaching resources and demands, developing new MEng-specific courses seems improbable.

  The issue has been discussed by the MMEGSC and the following solutions are now in place: a) ten graduate core courses have been identified (two per research group) that follow a common course syllabus irrespective of who is the course instructor. The course syllabus is followed closely in all offerings; b) the MEng students are encouraged to participate in the courses that are specifically designed for them (GDip core courses). Starting Fall 2016, MME has an additional orientation for new MEng students where the GDips and courses offered specifically for them is introduced.

- *"Some students felt that when a graduate student is promoted directly to the PhD program without completing their MASc thesis they are faced with having to take the comprehensive examination too soon after entering the PhD program. As a result they felt that they are not given enough time to prepare a good thesis proposal"*.

  MME has requested that the timeline for PhD comprehensive for student transferring from MASc to PhD be changed from 4 terms after starting graduate studies to four terms after transferring to PhD. This request has been approved by the Engineering Graduate Studies Committee.

Recommendations that may lead to major changes in the programs

3) The review committee had the following two recommendations that MME Dept. believes would need major changes to our current programs and hence should be included in the long-term planning of the department. These are:

   - *"Exploring and documenting the pros and cons of allowing international students to enroll in its MEng program are encouraged"*.

   - *"MME may want to examine its Ph.D. Comprehensive Examination procedure. The present procedure in which the student submits a thesis proposal and is then, in a single examination, first questioned about the proposal and then questioned about their background knowledge may need modification. Two separate examinations, one dealing with background knowledge and one dealing with a thesis proposal, may have to be considered"*.

     Both recommendations were discussed at Department meeting and further considered by the MMEGSC. The department has approved admission of visa MEng students starting fall 2016.

     A single comprehensive exam is common practice across Faculty of Engineering. The advantages and disadvantages of two separate background and proposal comprehensive exam is an ongoing discussion in MMEGSC. The logistics burden (exam chair, committee members, and exam question bank) of conducting two separate exams is considerable and beyond department's jurisdiction (Faculty provides examination Chair, and internal external examiner is required).

Additionally, and after the self-study assessment, the Department has enhanced its MEng program by:

a) To ensure that extensive knowledge and understanding of the fundamental concepts embodied in mechanical, materials and/or mechatronics engineering is gained through the program, MEng students are now required to take two of their courses from the list of the MME graduate core courses.

b) A 'Seminar Milestone' in the form of participation in four of department research seminars and workshops has been added to the MEng program requirements.

Recommendations that were not selected for implementation: None