I. Masters of Science Degree in Microsystems Engineering & Nanotechnology

Microsystems Engineering Program
Kate Gleason College of Engineering

Abstract

The Microsystems Engineering program is proposing a M.S. degree in Microsystems Engineering and Nanotechnology that will complement and strengthen the university's multidisciplinary research and educational efforts in micro- and nanoscale systems. The program will support the existing Ph.D. degree in Microsystems Engineering and allow alternative paths for students pursuing their graduate degree. It will provide more students an opportunity to pursue a degree in these fields, allowing them to explore curriculum and research activities addressing the numerous technical challenges of microsystems and nanotechnology in an interdisciplinary context. Consequently, the students will be well prepared for careers in a wide range of fields that directly make use of microsystems and nanotechnology.

II. Goals and Justification of the Program

The Microsystems Engineering Ph.D. program was established in 2002 to create a unique educational and research experience that fills the critical need for an expanded knowledge base and expertise in the innovation, design, fabrication, and application of micro- and nano-scale devices, components and systems. There is now strong demand and need for a complementary M.S. degree designed to develop graduates who will become researchers and professionals in microsystems and nanotechnology. This M.S. degree will address gaps in the existing Microsystems Engineering P.D. program and create new opportunities for faculty, students and graduates as follows:

1. It will grow the overall Microsystems Engineering program by providing a M.S. degree option that would have broader appeal to potential students.
2. It will serve as a multidisciplinary program focused on all micro and nano-scale devices, components and systems that cannot be met within the discipline-specific M.S. programs that currently exist.
3. It will provide a means for identifying promising graduate students for the Ph.D. program.
4. It will allow a limited number of Ph.D. students not able to continue Ph.D. study to graduate with a M.S. degree upon finishing M.S. program requirements.

There is a strong need for graduates trained in fields of microsystems and nanotechnology. Over the past decade, economic growth has been driven by these technologies in many areas including telecommunications, imaging, electronics and biomedical diagnostics and treatment. In short, nano- and micro-scale devices and systems are smaller, faster, cheaper, and more reliable than their macroscopic counterparts. It is likely that in the near future, a majority of product types will have microsystems and nanotechnology incorporated into them.

The training of M.S. graduates in microsystems and nanotechnology inherently requires a multidisciplinary approach. This is because the development, design, and manufacture of microsystems draw upon the collective knowledge base of electrical, mechanical, chemical, optical, computer, microelectronic, software, industrial, and systems engineering, as well as materials science, physics, chemistry, imaging science, and product development. The integration of such a broad range of disciplines in an educational program is very challenging. To be relevant, such a program must be interdisciplinary and explore new scientific and engineering territories that exist at the boundaries of conventional disciplines. RIT's Ph.D. program in Microsystems Engineering was created to address this specific need and can be directly adapted to prepare graduates in a complementary M.S. program.

The proposed M.S. program will achieve success for its graduates by realizing the following educational goals:

- Demonstrate foundational understanding of micro and nano-scale concepts and technology and be able to apply concepts to specific domain areas;
- Provide the ability to describe and explain literature and publications in specific microsystems and nanotechnology areas;
- Enable critical evaluation of existing research in order to propose and execute viable research directions, strategies, methods, and evaluations;
- Provide the foundation to explain technical material via written reports and oral presentations.

IV. Summary of New Program Curriculum

The M.S. degree will require 30 semester-credits including microsystems, nanotechnology, and interdisciplinary engineering and science. The degree requires students to identify a major technical interest area supported by at least three technical courses. Additional electives must also be taken to support/complement the technical interest area. Since the M.S. degree is interdisciplinary, students will have the ability to take graduate courses outside of the program as long as they meet program requirements and gain the approval of their advisor. Finally, the students must complete a capstone experience by choosing either an advisor-guided M.S. Research Project (3 credits) or M.S. Thesis (6 credits). If the student elects to do the project option, they must complete one additional elective course. The thesis option requires the formation of a thesis committee with a written final thesis manuscript and oral defense. The following table summarizes the curriculum:

	Description	**CHs**
Foundation Courses	Students will complete the following foundation courses that are shared with the Ph.D. program: 1. Introduction to Nanotechnology and Microsystems (MCSE-702)	9

	2. Material Science for Microsystems Engineering (MCSE-703) *3.* Theoretical Methods in Materials Science and Engineering (MTSE-704)	
Major Technical Interest Area	Students complete a sequence of at least three courses in a major technical area. The courses can be taken from graduate courses available to Microsystems Engineering Ph.D. students, with advisor approval.	9
Elective	Students will take at least two electives that support their major technical area (6 credits). If the student elects to do a final project then they must take one more course (9 total credits).	6 / 9
Capstone Research Experience - Project - Thesis	Students will be required to conduct original research in their major technical area. The student can choose to either do a project (3 credits) or thesis (6 credits). The project will require a final written report that the advisor must approve. The thesis option requires a thesis committee and a final written/oral defense.	3 / 6
TOTAL		30

The following are examples of major technical interest areas and potential courses.

Microfluidics	**Nanophotonics**	**Nanomaterials for Microsystems**
Fundamentals & Applications of Microfluidics (MCSE)	Lasers (MCSE-713)	Quantum Mechanics (MCSE-714)
Applied Biofluidic Mechanics & Microcirculation (MCSE-610)	Nonlinear Optics (MCSE-712)	Thin Film Science & Technology (MCSE)
Emulsion Science and Colloidal Dispersion (MCSE)	Integrated Optical Devices and Systems (MCSE-731)	Microelectronic Fabrication (MCEE-701)
Computation Fluid Dynamics (MECE-731)	Optoelectronics (MCSE-771)	Solid State Science (MTSE-703)
Microscale Separation (BIME)	Modern Optics for Engineering (EEEE-705)	Introduction to Electron Microscopy (IMGS-724)
Biomedical Microsystems	**Photovoltaics**	**Additive Manufacturing**
Fundamentals of Biomedical Microsystems (MCSE)	Compound Semiconductor Materials & Devices (MCSE)	Rapid Prototyping and Manufacturing (ISEE-741)
Microsystems for Global Health (MCSE)	Solid State Science (MTSE-703)	Lasers (MCSE-713)
Applied Biofluidic Mechanics & Microcirculation (MCSE-610)	Quantum Mechanics (MCSE-714)	Polymer Science (MTSE-702)
	Photovoltaic Science and Engineering (MCEE-720)	Functional Printing (ISEE)
	Thin Film Science & Technology (MCSE)	Thin Film Science & Technology (MCSE)

Students who have demonstrated strong research potential along with good academic standing during their first year of M.S. studies may apply to be admitted into the Ph.D. program in Microsystems Engineering. If admitted, they will need to take the Ph.D. Qualifying Exam after one semester (typically during the January Intersession). If they pass, they may continue the Ph.D. program; otherwise they will be transferred back into the M.S. program and can then complete the M.S. degree requirements. Relatedly, Ph.D. students who fail the Ph.D. Qualifying Exam may elect to transfer into the M.S. program. Consequently, there are several tracks that students could take through the programs. The following table describes the possible tracks along with program commitments to stipend and tuition:

Track	**AY1 Fall-Spring**	***Stipend & Tuition***	**AY1 Summer**	**AY2 Fall**	***Stipend & Tuition***	**AY2 Inter-session**	**AY2 Spring**	**AY2 May**
M.S. to Ph.D.	Courses	*No Stipend, Tuition Discount*	Apply to Ph.D. Program	Admitted to Ph.D.	*Advisor: Stipend, Program: Tuition*	Ph.D. Qualifying Exam	Pass: Ph.D. Program	Continue Ph.D.
							Fail: Transfer to M.S.	Graduate M.S.
M.S. Only	Courses	*No Stipend, Tuition Discount*	*Optional*	Courses / (*Thesis*)	*No Stipend, Tuition Discount*	*Optional*	Thesis / Project	Graduate M.S.
Ph.D. to M.S.	Courses	*Program : Both*	Failed Ph.D. Qualifying Exam	Transfer into M.S. program	*No Stipend, Tuition Discount*	*Optional*	Thesis / Project	Graduate M.S.

V. Fit with RIT Mission and Strategic Direction

The M.S. in Microsystems Engineering and Nanotechnology is very well aligned with RIT's mission and strategic plan:

- *Development of curricula and advanced scholarship and research relevant to emerging technologies:* Micro and nano-scale technologies are being integrated into an ever-expanding range of devices and systems. The proposed program will prepare students through both coursework and research to address current and future opportunities that make use of these promising technologies. The multidisciplinary nature of the M.S. program will ensure that students have both the foundation and specializations required to work in these emerging fields.

- *Motivation of students through stimulating and collaborative experiences:* The Microsystems Engineering program inherently is a multidisciplinary collaborative effort that involves faculty and students from KGCOE (Kate Gleason College of Engineering), COS (College of Science), GIS (Golisano Institute for Sustainability) and others. Interdisciplinary collaboration is built into the current Microsystems Engineering program and will continue to be a key part of the M.S. degree.

- *Scholarship:* The M.S. program will continue the spirit of scholarship that is inherently part of the Microsystems Engineering program. Specifically, it will provide opportunities for even more students to participate in original research, including, publishing, presenting and working on externally funded grants.

VI. Synergy with other Programs

The M.S. in Microsystems Engineering and Nanotechnology will expand RIT's multidisciplinary efforts with a wide-range of existing programs. This is combined with an offering of new opportunities for students to learn and pursue research in microsystems and nanotechnology. Specifically, the new program will allow students to focus on a wide-range of micro- and nanoscale devices and systems and draw on the courses, faculty and laboratory resources available in other programs. The degree is not expected to have a significant impact on enrollment in other M.S. degree programs and is expected to increase the number of students enrolled in current courses.

The M.S. program will also strengthen the current Microsystems Engineering program by providing new opportunities for students and faculty. Specifically, students from a wide range of backgrounds will be able to gain expertise in micro and nanoscale systems at the M.S. level. These students will carry out original research with Microsystems Engineering faculty and some may continue into the Ph.D. program.

VII. Administrative Structure

The M.S. in Microsystems Engineering and Nanotechnology will be administered by the Microsystems Engineering Ph.D. Program in the Kate Gleason College of Engineering. Consequently, the Ph.D. director will oversee administrative duties. Furthermore, all faculty who are currently affiliated with the Ph.D. program will be potential advisors/committee members for the M.S. students.

VIII. Enrollment Management Expectations

The new degree will primarily attract students who are interested in acquiring a M.S. degree with the expectation of continuing in the Microsystems Engineering Ph.D. program. It will also appeal to students wishing to obtain a terminal Master's degree with a focus on a specific micro/nanoscale technology.

The admission requirements for the M.S. degree are the same as the Ph.D. program. Students from a wide range of backgrounds can apply, provided they have a Baccalaureate or equivalent degree in the physical sciences or engineering. The students must also have a minimum GPA of 3.0 and GRE score of 156 Verbal, 156 Quantitative and 3.5 Writing.

We estimate that five M.S. students will be accepted to the program each year, reaching a steady state of eleven students enrolled at any given time. The Microsystems Engineering Ph.D. program currently receives about fifty qualified applicants each year and this number is expected to grow. The Ph.D. program now supports about twelve new Ph.D. students annually and it is likely that some of the applicants will be interested in the M.S. program as a means of preparing for further study. While we will not offer full scholarships for the M.S. program, we expect that the standard M.S. tuition discount will be enough of an incentive to applicants.

A review of the enrollment analysis has been certified by Diane Ellison, Assistant Vice President in Graduate Enrollment Services, and the following is a direct response from her to Professor Bruce Smith, Director of the Microsystems Engineering Ph.D. Program:

Bruce,

Jim Miller and I have reviewed the concept paper for a new Master of Science degree in Microsystems Engineering, and support the following enrollment planning scenario:

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
FTE	*5*	*10*	*11*	*11*	*11*

It is expected that enrollment for this program will come primarily from the existing applicant pool, in particular the Microsystems PhD. Information on the MS degree will be available to the external market, so it will be important to clearly distinguish the program from existing masters degrees offered though the College to avoid generating confusion in the market.

These enrollment numbers are based on the following assumptions:

1. *The program will be offered entirely on campus, and attract primarily full-time students.*
2. *The program requires no incremental resources, as indicated in the concept paper.*
3. *A 25% discount rate on overall tuition revenue should be used for planning. Any additional funding support will come from department and outside resources.*
4. *Students will complete the program in four semesters.*
5. *The timing of the approval, and on an ongoing basis the admission process, will affect enrollment numbers.*

Please contact me if you have additional questions.

Diane Ellison, Assistant Vice President
Part-time and Graduate Enrollment Services
Rochester Institute of Technology

IX. Impact on Resources

The M.S. program will not have a significant impact on resources since it has been designed to draw upon the resources that currently exist to support the Microsystems Ph.D. program:

- It will use the same library resources, labs, faculty and support personnel that currently exist within Microsystems Ph.D. program.
- The Ph.D. admissions committee will be responsible for M.S. admissions.
- All the M.S. courses are shared with those currently available to support the Ph.D. curriculum. Consequently, the incremental enrollment projected for the M.S. program will be filling empty seats in existing courses, increasing course enrollment from approximately 5-10 students/class to 10-15. This should have no impact on classroom scheduling/availability. More importantly, it will not require incremental faculty to support the curriculum.

A cost analysis has been prepared using the *Concept Paper Budget Template* that is available on the Provost's website. Unfortunately, this template is inappropriate for programs, like this one, that are designed to leverage existing resources. Indeed, the template automatically assumes that incremental faculty resources are required if incremental credit hours are being taught, which is not the case for this program. Based on the detailed calculations provided by this template, recognizing that no incremental faculty will be required, ***the program is projected to generate in excess of $1.5 million in net revenue over five years.***

X. Conclusion

The M.S. in Microsystems Engineering and Nanotechnology will be a unique program that focuses on interdisciplinary research of micro- and nanoscale devices and systems. Graduates will be strongly positioned to pursue a career in emerging technologies and in some cases will be able to continue on to a Ph.D. Consequently, this new degree will strengthen the current Microsystems Engineering program and will complement existing graduate programs throughout the university.