UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

MEMORANDUM

To: Executive Committee of Faculty Council (October 3, 2017)
Faculty Council (October 23, 2017)

From: Professor Deepa Kundur
Chair, Division of Engineering Science

Date: October 11, 2017

Re: **Creation of a Machine Intelligence Stream in Engineering Science**

REPORT CLASSIFICATION

This is a major policy matter that will be considered by the Executive Committee for endorsing and forwarding to Faculty Council for vote as a regular motion (requiring a simple majority of members present and voting to carry).

SUMMARY

In February 2017, an interdisciplinary working group was struck by the Division of Engineering Science to examine the idea of developing a stream (also known in the Faculty as a major or option) in the area of Machine Intelligence (MI).

This is strongly supported by Engineering Science students in the areas of robotics and software engineering, and among faculty, the Engineering Science Advisory Board, alumni and employers, there is consensus that the stream will be of great interest and benefit to the Division, Faculty and University.

The academic rationale for creating the stream, along with a description of need and demand, admission and eligibility requirements, program requirements, program structure and learning outcomes, and faculty and space requirements are described in the attached major modification proposal.

CONSULTATION

In creating the proposal, the working group consulted with the Division's and Faculty's curriculum committees, Chairs and Directors, Vice-Deans, the Engineering Science Advisory

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Board, various faculty members working in MI and related fields in Engineering and Arts and Science, members of industry, and others.

MOTION

THAT the creation of a Machine Intelligence stream within the Division of Engineering Science's undergraduate program be approved, effective September 2018, as described in the attached major modification proposal.

University of Toronto
Major Modification Proposal:
Specialist or Major where there is an Existing Major or Specialist

What is being proposed:	Machine Intelligence Stream[1]
Department / Unit (if applicable):	Division of Engineering Science
Faculty / Academic Division:	Applied Science and Engineering
Dean's Office Contact:	Caroline Ziegler, Governance and Programs Officer
Proponent:	Deepa Kundur, Chair, Division of Engineering Science
Version Date:	October 10, 2017

1 Summary

In February 2017, a working group was struck by the Division of Engineering Science to examine the idea of developing a stream[1] in Engineering Science in the area of Machine Intelligence (MI). Interest in the stream has been encouraged by a few recent developments, including the exceptionally strong interest from Engineering Science students in the areas of Robotics and Software Engineering. There has also been a significant investment in related R&D through initiatives such as Toronto's Vector Institute, which has received financial backing from the provincial and federal governments, and several industry partners. This stream is consistent with University and provincial efforts to retain many of the top graduates in MI from the University of Toronto in Ontario, and in fact, several large companies have moved their related divisions to Toronto, including Thomson Reuters and General Motors, with the intention of hiring hundreds of data scientists. Moreover, many of Canada's largest companies in management consulting, finance and other sectors have stated a desire to expand hiring in this area in the coming years, and have started exploring what MI can bring to their businesses, while new firms are being established with a strong core focus on MI, such as Daisy Intelligence (which is

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[1] Engineering Science streams are referred to within the Faculty as "options", and in the undergraduate calendar and on student transcripts as "majors".

led by a graduate of the Engineering Science program). In short, the demand for graduates in this area has already outpaced supply, and this is set to continue in the future.

Machine Intelligence is well suited to build upon the multidisciplinary foundation curriculum offered by Engineering Science, and in particular the rigorous approach to mathematics, and the established focus on computer programming and hardware design. There are eight existing streams in Engineering Science: Aerospace Engineering, Biomedical Systems Engineering, Electrical and Computer Engineering, Energy Systems Engineering, Engineering Mathematics, Statistics and Finance, Infrastructure Engineering, Engineering Physics, and Robotics Engineering. Although there are some overlapping courses in different streams, each stream maintains its own unique curriculum. The MI stream has some overlap with the streams in Electrical and Computer Engineering, Robotics Engineering, and Engineering Mathematics, Statistics and Finance, however, there is sufficient distinctiveness. The Electrical and Computer Engineering stream provides students with a broad background in both disciplines, and while there is some opportunity to explore MI, the stream does not provide a strong focus in this area. The Robotics Engineering stream includes some MI curriculum, but emphasizes a whole- systems perspective to robotics, using a multidisciplinary approach to planning, perceiving, acting and system integration. Within the Engineering Mathematics, Statistics and Finance stream, there is an emphasis on mathematics and modelling and some opportunity to examine the relationship between MI and financial applications, but again, this emphasis is quite limited.

Outside of the Engineering Science program, the Faculty's Industrial Engineering undergraduate program offers an area of focus in information engineering, which includes only minimal overlap in scope with the proposed MI stream. The Department of Computer Science in the Faculty of Arts and Science provides a strong undergraduate degree with opportunities to focus on Artificial Intelligence, Scientific Computing, Natural Language Processing and Computer Vision, however, the proposed stream offers a uniquely "engineering approach" to the field. This distinction is further explored later in the proposal.

In speaking with various stakeholders of the Division of Engineering Science, including students, faculty, alumni, employers and the Engineering Science Advisory Board, there was a strong consensus that a new stream in this area would be of great interest and benefit.

2 Effective Date

We propose an effective start date for year 3 students of September 2018. Hence, students currently enrolled in both first and second year in the Division of Engineering Science will have an opportunity to select this stream for their final two years of study.

3 Academic Rationale

The University of Toronto and the Faculty of Applied Science and Engineering are well suited to support a stream in this rapidly evolving field. There are already several faculty members with relevant research interests and industry connections across various academic departments, including The Edward S. Rogers Sr. Department of Electrical and Computer Engineering (ECE), the Department of Mechanical and Industrial Engineering (MIE), the

Institute for Aerospace Studies (UTIAS), and the Centre for Management of Technology and Entrepreneurship (CMTE). Both the Faculty of Applied Science and Engineering and the Faculty of Arts and Science are planning for several new faculty hires in MI and related fields. The University of Toronto has unique strengths in the field, including Professor Geoff Hinton's work in deep learning, Professor Brendan Frey's work in machine learning and genome biology, and Professor Richard Zemel's work with Bayesian optimization. Related U of T startups include WhetLab, which was acquired by Twitter; DNNresearch, Hinton's company acquired by Google; and Frey's Deep Genomics.

The Engineering Science program has a long history of offering a dynamic curriculum, reflective of cutting edge academic and industry research, with an ability to be flexible and offer new, multidisciplinary streams when demand exists. The unique curricular strengths of the Engineering Science foundation (years 1 and 2) have influenced the design of the stream.

Engineering Science is a demanding program with a special focus on learning from first principles, allowing students to examine and solve problems at a more fundamental level. It has a unique 2+2 structure, beginning with two years of common curriculum covering basic mathematics and sciences more intensively than is normal for engineering programs, and providing additional breadth in engineering science and design. This is followed by an accelerated discipline-specific curriculum in years 3 and 4, focused in one of the eight streams.

The multidisciplinary approach utilized in the first two years ensures students enter year 3 with the experience required to continue to work across disciplines, which will be critical in a stream in Machine Intelligence. Students also enter year 3 with experience in both hardware and software, including courses in computer programming and digital systems design, along with a course in probability and statistics, and a major design project that requires the design and integration of hardware, software and mechanical systems. Engineering Science students are educated in a way that encourages flexibility, disciplinary integration and critical thinking; all skills essential for working in a rapidly developing field like MI.

Although related areas of undergraduate study are offered through the Department of Computer Science, Engineering can offer a unique perspective on MI, namely one that emphasizes design thinking and a whole-systems approach. Design thinking, a method for the practical and creative resolution of problems, encourages both divergent thinking to ideate many solutions, and convergent thinking to realize the best solution. Engineering students are encouraged to develop their design thinking skills starting in the first semester of their studies, and this thinking is emphasized throughout the program, allowing graduates to frame and solve problems in the MI field, or appropriately and innovatively apply MI tools to problems in various application areas, which are as diverse as finance, education, advanced manufacturing, healthcare and transportation. Engineering Science students in the MI stream will have exposure to various focus areas reflective of the different components of a MI system, including computation, data and information, hardware, mathematics and modelling, control theory, signal processing, and hardware design, producing a well-rounded graduate capable of working on the various aspects of algorithm design, implementation and application.

It is expected that the stream will have a positive impact on the Engineering Science program, elevating the quality of the program as a whole, with the inclusion of Machine Intelligence as a cutting-edge and multidisciplinary field. Departments offering courses (The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, Department of Mechanical and Industrial Engineering, University of Toronto Institute for Aerospace Studies and the Department of Computer Science) will have the opportunity to engage with the high caliber of students attracted to Engineering Science, and recruit participants as potential graduate students. There may be unique opportunities for cross-stream collaboration, for example, students in other streams with an interest in applying MI to their own stream may be able to access some of the courses, or collaborate with students across streams on curricular or co-curricular design projects. Alongside the proposed stream, the Faculty is also working towards the creation of a minor in Machine Intelligence, which will be available to students in Engineering Science's other streams and students in other undergraduate programs in the Faculty.

4 Need and Demand

As noted, various stakeholders of the division and university have highlighted the critical need for this new stream. Alumni, industry partners and the Engineering Science Advisory Board have provided the Division of Engineering Science with a comprehensive view of the expected growth in machine intelligence, though the establishment and growth of new start-ups and the growth of MI divisions within existing organizations. The focus on MI in the City of Toronto and the University of Toronto is evident in the recent establishment of the Vector Institute, which aims to encourage more students to focus on deep learning. There is clearly an emphasis on keeping the brightest minds in MI in Canada while growing our local sector, and Engineering Science is well-positioned to help fill the expected gap in graduates.

In addition to industry, there is a growing number of opportunities for students to pursue graduate research in Machine Intelligence. We expect several graduates will continue at the University of Toronto, however, several other institutions in Canada, the US and overseas are growing their programs in this area, including University of Waterloo, University of Montreal, University of Alberta, University of British Columbia, Carnegie Mellon University, University of California at Berkeley, Stanford University, New York University and MIT. In fact, a number of recent Engineering Science graduates have pursued graduate programs in Machine Intelligence and related areas at several of these institutions.

Currently, the three streams within Engineering Science related to Machine Intelligence (Electrical and Computer Engineering; Robotics Engineering; and Engineering Mathematics, Statistics and Finance) are the most popular streams by a healthy margin, representing approximately 70% of the current year 3 class. In the last five years, more than 80 students have pursued MI-related fourth year thesis projects under the supervision of over 50 faculty members. The Division of Engineering Science recently conducted a survey with students entering second year, and out of 56 respondents, 47 students indicated some interest in the stream.

Furthermore, if a stream is established in Engineering Science, we expect it to attract new, top students from across the country and internationally who are interested in a career in Machine Intelligence. This may increase competition for spots in the program, as we do not anticipate changing the overall program enrolment targets as a result of the new stream.

5 Admission / Eligibility Requirements

The Engineering Science program attracts top students from across Canada and around the world, with a mean entrance average of over 94%. Incoming students from the Ontario system are required to complete the Ontario Secondary School Diploma or equivalent, and the admissions average is calculated using English, Calculus and Vectors, Chemistry, Physics, Advanced Functions, and one additional U or M course. Once Engineering Science students are admitted into the program, and provided they meet the ongoing academic requirements to maintain their spot in the program, they can, at the end of their second year, select any one of the streams to complete in their third and fourth years. In other words, caps are not placed on any of the streams in the program.

6 Program Requirements

In the first two years, Engineering Science students take a common curriculum that is unique to the program. These courses provide a strong foundation in mathematics, science, engineering science and design. A "first principles" approach provides students with the opportunity to learn and apply concepts at a more fundamental level, and the breadth of the courses in the first two years offers students an excellent preparation for the upper-year Streams. A description of the years 1&2 curriculum can be found in Appendix C.

The following tables outline the courses that students are expected to complete in the Machine Intelligence stream. The core courses are categorized as follows: computation (three courses), mathematics (two courses), and data and information (five courses). Students in the MI stream will also be required to take courses that are common to all streams in the Engineering Science program, including the Engineering Science Option Seminar, Economic Analysis and Decision Making, Complementary Studies Electives and the Engineering Science Thesis:

Fall Session - Year 3			Lect.	Lab	Tut	Wg
Algorithms and Data Structures	ECE345H1	F	3	0	1	0.5
Introduction to Machine Intelligence (New Course)	MIE3XXH1	F	3	0	1	0.5
Signal Analysis and Communications	ECE355H1	F	3	0	2	0.5
Matrix Algebra and Optimization (New Course)	ECE3XXH1	F	3	0	1	0.5
Economic Analysis and Decision Making	CHE374H1	F	3	0	1	0.5
Engineering Science Option Seminar	ESC301Y1	Y	1	0	0	

Winter Session - Year 3			Lect.	Lab	Tut	Wg
Systems Software	ECE353H1	S	3	3	0	0.5
Probabilistic Reasoning (New Course)	ECE3XYH1	S	3	0	1	0.5
Artificial Intelligence (New Course)	ROB3XXH1	S	3	0	1	0.5
Introduction to Machine Learning	ECE421H1	S	3	0	2	0.5
One (1) Technical Elective[2,3]		S				0.5
Engineering Science Option Seminar	ESC301H1	Y	1	0	0	0.2

Year 4			Lec	Lab.	Tu	Wg
Thesis	ESC499Y1	Y	3	2	0	1.0
Decision Support Systems	MIE451H1	F	3	1	1	0.5
Two (2) HSS/CS Electives[1]		F/S /Y				1.0
Machine Intelligence Capstone Design (New Course)	ECE4XXH1	S	0	0	5	0.5
Distributed Systems OR Computer Systems Programming[1]	ECE419 or ECE454		3/ 3	1.5/ 3	1/ 0	0.5
Three (3) Technical Electives[2,3]						

Notes:

1. Machine Intelligence Major students must complete 2.0 credits of Technical Electives, and 1.0 credits of Complementary Studies (CS)/Humanities and Social Sciences (HSS) electives in Years 3 and 4. All students must fulfill the Faculty graduation requirement of 2.0 CS/HSS credits, at least 1.0 of which must be HSS. ESC203H1 is 0.5 HSS. Technical and CS/HSS Electives may be taken in any sequence.

2. Please note, some courses have limited enrolment. Availability of elective courses for timetabling purposes is not guaranteed. It is the student's responsibility to ensure a conflict-free timetable. Technical Electives outside of the group of courses below must be approved in advance by the Division of Engineering Science.

3. Students enrolled in the Machine Intelligence Major may take a maximum of four (4) 300- or 400-series courses in the Department of Computer Science (CSC).

4. Students may take Computer Systems Programming (ECE454H1) in year 3 by moving Economic Analysis and Decision Making (CHE374H1) to year 4.

Technical Electives

Students may select their four technical electives from any combination of the following groupings, which exist to help students with their course selection. New elective options will be considered on an annual basis, in particular as Machine Intelligence and related disciplines grow at the University of Toronto:

Artificial Intelligence:
CSC310: Information Theory
CSC401: Natural Language Processing
CSC420: Introduction to Image Understanding
CSC321: Neural Networks
CSC485: Computational Linguistics
CSC486: Knowledge Representation and Reasoning
ECE521: Inference Algorithms
MIE457: Knowledge Modeling and Management
MIE566: Decision Analysis

Software:
CSC343: Introduction to Databases
CSC444: Software Engineering
ECE358: Foundations of Computing
ECE568: Computer Security
ECE419: Distributed Systems
ECE454: Computer Systems Programming

Hardware:
ECE470: Robot Modeling and Control
ECE532: Digital Systems Design
ECE411: Real-Time Computer Control
ROB501: Computer Vision for Robotics

Mathematics and Modelling:
AER336: Scientific Computing
ECE356: Linear Systems and Control Theory
ECE557: Systems Control
STA302: Methods of Data Analysis I
STA410: Statistical Computation
MAT336: Elements of Analysis
MAT389: Complex Analysis

Design in the Machine Intelligence Stream

The opportunity for engineering design experience is a critical component of any Engineering Science Stream. Students will learn about Machine Intelligence design from a systems perspective through an introductory course, which will include a team design project. The multidisciplinary curriculum will offer students an opportunity to learn about all aspects of the MI design process. Finally, the stream will include a capstone design course in the fourth year, along with a required thesis to ensure significant hands-on experience.

7 Program Structure, Learning Outcomes, and Degree Level Expectations

As with the existing streams in the Engineering Science program, the learning outcomes for the proposed Machine Intelligence stream match those at the program-level. These program-level learning outcomes are:

i. To produce an academically enriched program for young men and women seeking a significant academic challenge;
ii. To produce engineering science graduates who have a deep understanding of mathematics, physics, chemistry, biology and the engineering sciences, and can apply and integrate this knowledge to solve complex problems;
iii. To prepare men and women for careers in the engineering sciences within academia, industry and the public sector as well as careers in other professions;
iv. To produce engineering science graduates who have an understanding of the impact of technology on individuals, groups and society-at large;

<ol type="i" start="5">
To educate men and women as global citizens and leaders of the society in which they live and work.

In addition, by the end of the fourth year, the Machine Intelligence students will be able to:

<ol type="i">
Formulate engineering problems of relevance to the field of machine intelligence.
Employ machine learning and artificial intelligence tools innovatively, effectively and broadly to solve complex engineering problems.
Translate a given application's needs or goals into a set of requirements that a machine intelligence system must achieve.
Take a "systems approach" to machine intelligence design: develop, design and implement approaches for learning architectures, feature selection from input data, training strategies, and performance evaluation metrics for impact assessment in real world problems.
Take a "first principles approach" to machine intelligence engineering through a deep understanding and application of mathematics and modelling.
Integrate knowledge of computer hardware and software systems in the design and application of Machine Intelligence tools.
Design machine intelligence systems for a variety of applications.
Appreciate the limits of machine intelligence systems, and the need to enhance the human-to-machine interface.
Describe the relationship between machine intelligence and society, and its implications for the economy, human health, safety and privacy.

The degree level expectations (DLEs) for the Faculty's undergraduate programs, including Engineering Science, are appended (see Appendix D). They closely map to the graduate attributes (GAs) of the Canadian Engineering Accreditation Board (CEAB), which is responsible for conducting cyclical accreditation reviews of each undergraduate program. The most recent (2012) CEAB accreditation of the Engineering Science program was based on a measurement of academic units (AUs) across categories (such as engineering design and engineering science), but moving forward, we will be assessed based on both AUs and GAs. A mapping of the degree-level expectations with the graduate attributes is as follows:

Depth and Breadth of Knowledge

This is tracked by the GA "knowledge base for engineering", and met by the unique 2+2 structure of the Engineering Science program, in which students gain breadth through a two year foundation in math, science, engineering science, design and social science/humanities, followed by two years of specialization, which provides depth in one of the eight upper-year streams.

Knowledge of Methodologies:

This is tracked by the GAs "problem analysis", "investigation", "design" and "use of engineering tools", and met by the numerous design projects and laboratory exercises conducted by students in their courses, as well as their fourth year thesis.

Application of Knowledge:

This is tracked by the GAs "design" and "investigation", and met by the numerous design-oriented projects conducted by students in their courses, as well as the fourth year thesis.

Communication Skills:

This is tracked by the GAs "communication skills" and "individual and teamwork", and emphasized in the following courses: ESC101: Engineering Science Praxis I, ESC102: Engineering Science Praxis II, ESC203: Engineering and Society, ESC301: Engineering Science Option Seminar, ESC499: Engineering Science Thesis, and ECE4XX: Machine Intelligence Capstone Design.

Awareness of Limits of Knowledge:

This is tracked by the GA "lifelong learning" and emphasized in particular in ESC499 (Engineering Science Thesis) and in upper-year courses that introduce students to open-ended questions in the subject matter of the course.

Autonomy and Professional Capacity:

This is tracked by several GAs, including "professionalism", "impact of engineering on society and the environment", "ethics and equity" and "economics and project management". These areas are emphasized in the following courses: ESC101: Engineering Science Praxis I, ESC102: Engineering Science Praxis II, ESC203: Engineering and Society, ESC301: Engineering Science Option Seminar, and CHE374 (Engineering Economics.

Quantitative Reasoning:

This is tracked by the GAs "investigation" and "problem analysis", and met by the numerous laboratory exercises and problem solving-focused assignments conducted by students in their courses.

Information Literacy:

The Faculty requires all students to develop an advanced understanding of how to obtain, manipulate and evaluate information; how to bring diverse sources together to develop a comprehensive understanding of specific issues, and how to solve problems or apply the scientific method to create further knowledge in the discipline. This DLE is met by many aspects of our curriculum, but mainly emphasized in various design-oriented courses and ESC499 (Engineering Science Thesis).

An accreditation analysis, summarized in the following table, was conducted to ensure the Machine Intelligence stream curriculum would meet the total AU requirements and the requirements in each category, as outlined by the CEAB. Accreditation Units are generally defined by hours of instruction in five major subject areas.

Accreditation Unit Analysis

Category	Required Totals	Machine Intelligence Stream
Complementary Studies	225	241.8[1]
Math	195	316.8
Natural Science	195	225.8
Math + Natural Science	420	542.6
Engineering Science	225	829.5
Engineering Design	225	296.8
Engineering Science + Engineering Design	900	1126.2
Total	1950	1923.5[2]

Notes:

1. The average CS course value has been calculated as 29.4 according to the Faculty's 2012 accreditation report. This value has been used for the 3 CS/HSS courses selected by students, contributing to the total in this category.
2. The Total AU count does not include four technical electives selected by students.

All 12 of the CEAB's graduate attributes have been mapped to the Machine Intelligence stream curriculum, based on a preliminary analysis, as outlined below. Upon program commencement, and consistent with practice throughout the Faculty's undergraduate programs, data from this stream will be regularly collected and evaluated to support the graduate attributes process.

Engineering Graduate Attributes Mapped to the Machine Intelligence Stream

Graduate Attribute	Relevant Courses
A knowledge base for engineering	All core technical courses
Problem analysis	Most core technical courses
Investigation	ESC499
Design	MIE3XX; ESC301; MIE451; ECE4XX
Use of engineering tools	ECE345; ECE355; ECE3XX; ECE353
Individual and team work	MIE3XX; ECE4XX
Communication skills	ESC301; ESC499
Professionalism	ESC301; ESC499; ECE4XX

Graduate Attribute	Relevant Courses
Impact of Engineering on Society and the Environment	ESC301; MIE3XX; ECE4XX
Ethics and equity	ESC301; ESC499
Economics and project management	CHE374
Life-long learning	ESC499

Upon approval of the MI stream by Faculty Council, the CEAB will be informed of the new stream and planned rollout.

8 Resources

8.1.Faculty Requirements

The new stream will result in five new courses in years 3 and 4. These courses will be taught by faculty from The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, the University of Toronto Institute for Aerospace Studies, and the Department of Mechanical and Industrial Engineering. Four Faculty members have been tentatively assigned to these courses, and additional Faculty members who could serve as course instructors have been identified. Furthermore, we also expect to engage some of the planned new hires in both existing and new courses.

As evidenced by the number of Engineering Science students already engaged in related thesis projects, we anticipate there will be sufficient opportunities for both summer and thesis research with the existing faculty complement.

8.2.Space/Infrastructure

The stream will be supported by existing and planned facilities, including space in the Centre for Engineering Innovation and Entrepreneurship, a new building which will open in January 2018. Students in the stream will benefit from existing Engineering Science spaces, including our student common room with collaborative work space, and our computer laboratory.

9 Consultation

The interdisciplinary working group that created the proposal for a stream in Machine Intelligence included the following representatives:

Professor Jason Anderson (ECE)
Professor Tim Barfoot (UTIAS)
Professor Tony Chan Carusone (ECE)
Professor Jim Davis (UTIAS)
Professor Sven Dickinson (DCS)
Professor Stark Draper (ECE)

Mengli Duan, Engineering Science Student
Professor Mark Fox (MIE)
Professor Roger Grosse (DCS)
Professor Michael Gruninger (MIE)
Brendan Heath, Year 3 & 4 Student Counsellor (EngSci)
Professor Deepa Kundur (Chair, ESC/ECE)
Professor Yuri Lawryshyn (CHE)
Professor Lisa Romkey (ESC)Professor Scott Sanner (MIE)
Scott Sleeth, Curriculum Officer (ESC)

Consultation was also held with a number of individuals and groups throughout the planning process:

i. Faculty of Applied Science and Engineering Undergraduate Curriculum Committee, consisting of faculty representatives from each undergraduate program; the Vice-Dean, Undergraduate Studies; the Chair, First Year; the Associate Dean, Cross-Disciplinary Programs; undergraduate students; and the Registrar's Office
ii. Faculty of Applied Science and Engineering Chairs and Directors
iii. Division of Engineering Science Curriculum Committee
iv. Various faculty members working in MI and related fields in the Faculty of Applied Science and Engineering and in the Faculty of Arts and Science
v. Engineering Science Advisory Board
vi. Members of industry including Dr. Matthew Zeiler (Founder and CEO, Clarifai and Engineering Science Alumnus), Harris Chan (Advanced Software Engineer, Intel Corporation and Engineering Science Alumnus), Gary Saarenvirta (Founder and CEO, Daisy Intelligence and Engineering Science Alumnus) and representatives from Autodesk
vii. The Dean's Office in the Faculty of Arts and Science has been consulted, given the potential use of courses in the stream, primarily from the Department of Computer Science

10 Governance Process

Steps	Date
Development/consultation within Unit	February-August 2017
Consultation with Dean's Office	August 2017
Consultation with Vice-Provost's Office	September 2017
Approval by Unit	September 2017
Sign-off by Dean	September 2017
Approval by Faculty Council	October 23, 2017
Dean's Office submits to Provost's Office	October 2017
Vice-Provost's Office reports to AP&P	January 2018

Steps	Date
Vice-Provost's Office reports to Ontario Quality Council	July 2018

Appendix A: Core Course Descriptions

CHE374H1: Economic Analysis and Decision Making 3/0/1/0.5
Economic evaluation and justification of engineering projects and investment proposals. Cost estimation; financial and cost accounting; depreciation; inflation; equity, bond and loan financing; after tax cash flow; measures of economic merit in the private and public sectors; sensitivity and risk analysis; single and multi-attribute decisions. Introduction to micro-economic. Applications: retirement and replacement analysis; make-buy and buy-lease decisions; economic life of assets; capital budgeting; selection from alternative engineering proposals; production planning; investment selection.
AU: 100% CS

ECE345H1: Algorithms and Data Structures 3/0/2/0.5
Design and analysis of algorithms and data structures that are essential to engineers in every aspect of the computer hardware and software industry. Recurrences, asymptotics, summations, trees and graphs. Sorting, search trees and balanced search trees, amortized analysis, hash functions, dynamic programming, greedy algorithms, basic graph algorithms, minimum spanning trees, shortest paths, introduction to NP completeness and new trends in algorithms and data structures.
AU: 75% ES, 25% ED

ECE353H1: Systems Software 3/3/0/0.5
Operating system structure, processes, threads, synchronization, CPU scheduling, memory management, file systems, input/output, multiple processor systems, virtualization, protection, and security. The laboratory exercises will require implementation of part of an operating system.
AU: 100% ES

ECE355H1: Signal Analysis and Communications 3/0/2/0.5
An introduction to continuous-time and discrete-time signals and systems. Topics include characterization of linear time-invariant systems, Fourier analysis, linear filtering, sampling of continuous-time signals, and modulation techniques for communication systems.
AU: 100% ES

ECE3XXH1: Matrix Algebra & Optimization (**new course**) 3/0/1/0.5
A grounding in optimization methods and the matrix algebra upon which they are based. The first part of the course focuses on fundamental building blocks in linear algebra and their geometric interpretation: matrices, their use to represent data and as linear operators, and the matrix decompositions (such as eigen- and singular-vector decompositions) that reveal structural and geometric insight. The second part of the course focuses on optimization, both unconstrained and constrained, linear and non-linear, as well as convex and non-convex. Conditions for local and global optimality, first and second-order numerical computational techniques, as well as basic classes of optimization problems are discussed. Applications from machine learning, signal processing, and statistics are used to illustrate the techniques developed.
Pre-req: AER210 or MAT291; and MAT185 or MAT188
AU: 50% ES, 50% MATH

ECE3XYH1: Probabilistic Reasoning (**new course**) 3/0/1/0.5
Different classes of probabilistic models and how, based on those models, one deduces actionable information from data. The course will start by reviewing basic concepts of probability including random

variables and first and second-order statistics. Building from this foundation the course will then cover probabilistic models including vectors (e.g., multivariate Gaussian), temporal (e.g., stationarity and hidden Markov models), and graphical (e.g., factor graphs). On the inference side topics such as hypothesis testing, marginalization, estimation, and message passing will be covered. Applications of these tools cover a vast range of data processing domains including machine learning, communications, search, recommendation systems, finance, robotics and navigation.
Pre-req: STA286 or ECE302
AU: 25% ES, 75% MATH

ECE419: Distributed Systems 3/1.5/1/0.5

Design issues in distributed systems: heterogeneity, security, transparency, concurrency, fault-tolerance; networking principles; request-reply protocol; remote procedure calls; distributed objects; middleware architectures; CORBA; security and authentication protocols; distributed file systems; name services; global states in distributed systems; coordination and agreement; transactions and concurrency control; distributed transactions; replication.
Pre-req: ECE344 or ECE353
AU: 50% ES, 50% ED

ECE421H1: Introduction to Machine Learning 3/0/2/0.5

An Introduction to the basic theory, the fundamental algorithms, and the computational toolboxes of machine learning. The focus is on a balanced treatment of the practical and theoretical approaches, along with hands on experience with relevant software packages. Supervised learning methods covered in the course will include: the study of linear models for classification and regression, neural networks and support vector machines. Unsupervised learning methods covered in the course will include: principal component analysis, k-means clustering, and Gaussian mixture models. Theoretical topics will include: bounds on the generalization error, bias-variance tradeoffs and the Vapnik-Chervonenkis (VC) dimension. Techniques to control overfitting, including regularization and validation, will be covered.
Pre-req: STA286 or ECE302
Exclusion: CSC411
AU: 100% ES

ECE454: Computer Systems Programming 3/3/0/0.5

Fundamental techniques for programming computer systems, with an emphasis on obtaining good performance. Topics covered include: how to measure and understand program and execution and behaviour, how to get the most out of an optimizing compiler, how memory is allocated and managed, and how to exploit caches and the memory hierarchy. Furthermore, current trends in multicore, multithreaded and data parallel hardware, and how to exploit parallelism in their programs will be covered.
AU: 50% ES, 50% ED

ECE4XXH1: Machine Intelligence Capstone Design (**new course**) 0/0/5/0.5

A half-year capstone design course in which students work in small teams to apply the engineering design, technical, and communication skills learned previously, while refining their skills in teamwork and project management. The course will take a "systems approach" to machine intelligence design, where students will identify, frame and design solutions to real-world problems in the field. Students will engage with industry partners, and work through a process that results in a functional prototype. The resulting designs are assessed on their engineering quality and design credibility. In addition, each

student engages in individual critical reflection on their course activities, team performance, and on their growth as an engineering designer across their undergraduate program. Students are supported by a teaching team comprising both design and domain experts.
AU: 100% ED

ESC301Y1: Engineering Science Option Seminar 1/0/0/0.25

The Option seminar supports discipline specific discussions of ethics, professionalism, safety and standards and research in a seminar-based setting. Guest speakers, presentations and other activities will highlight various topics of interest, including the present and future research related to the Option. This course will be offered on a credit/no credit basis and the assessment will be through a combination of written assignments, presentations and tests. Concepts in Engineering Communication will be emphasized to support discussion and the development of the course deliverables.
AU: 50% CS, 50% ED

ESC499Y1: Thesis 3/2/0/1

Every student in Fourth Year Engineering Science is required to conduct a thesis on an approved subject under the supervision of any faculty member at the University of Toronto. The thesis provides students with an opportunity to conduct, document, and experience engineering related research as an undergraduate student. This course is structured to provide resources to support that process, in particular the documentation of research, through a series of lectures and workshops. While the final thesis document is the main deliverable, students are also required to submit a set of interim deliverables to support ongoing documentation and reflection.
AU: 10% CS, 90% ES

MIE3XXH1F: Introduction to Machine Intelligence (**new course**) 3/0/1/0.5

This course will provide students with an overview of the major, introduce them to some basic techniques, and illustrate those techniques through case studies. Techniques will include the basics of machine learning, e.g., linear regression, logistic regression, support-vector machines, neural networks, and the use of these techniques to improve decision making through improved predictions or directly in optimization models. A significant component of the course will be hands-on exposure to a state-of-the-art machine-learning software framework with a series of assignments, culminating in a design project where the students work in a team to build a larger-scale machine learning application, and communicate and demonstrate their accomplishments.
AU: 75%ES, 25%ED

MIE451H1: Decision Support Systems 3/1/1/0.5
This course provides students with an understanding of the role of a decision support system in an organization, its components, and the theories and techniques used to construct them. The course will cover basic technologies for information analysis, knowledge-based problem solving methods such as heuristic search, automated deduction, constraint satisfaction, and natural language understanding.
Pre-req: MIE253, MIE350
AU: 75% ES, 25% ED

ROB3XX: Artificial Intelligence (**new course**) 3/0/1/0.5
This course introduces the fundamental principles of artificial intelligence, and will explore the subject matter in rigorous mathematical terms. Topics include the history and philosophy of AI, search methods in problem solving, knowledge and reasoning, probabilistic reasoning, decision trees, Markov decision processes, natural language processing and elements of machine learning such as neural-network paradigms.
Pre-requisites: ECE345; STA286
AU: 100% ES

Appendix B: Technical Elective Course Descriptions

AER336: Scientific Computing 3/0/1/0.5
An introduction is provided to numerical methods for scientific computation which are relevant to the solution of a wide range of engineering problems. Topics addressed include interpolation, integration, linear systems, least-squares fitting, nonlinear equations and optimization, initial value problems, partial differential equations, and relaxation methods. The assignments make extensive use of MATLAB. Assignments also require knowledge of Fortran or C.
Pre-req: ESC103 and MAT185 AU: 40% MATH, 60% ES

CSC310: Information Theory 2/0/1/0.5
Measuring information. The source coding theorem. Data compression using ad hoc methods and dictionary-based methods. Probabilistic source models, and their use via Huffman and arithmetic coding. Noisy channels and the channel coding theorem. Error correcting codes, and their decoding by algebraic and probabilistic methods.

CSC321: Neural Networks 2/1/0/0.5
The first half of the course is about supervised learning for regression and classification problems and will include the perceptron learning procedure, backpropagation, and methods for ensuring good generalization to new data. The second half of the course is about unsupervised learning methods that discover hidden causes and will include K-means, the EM algorithm, Boltzmann machines, and deep belief nets.
AU: 100% ES

CSC343: Introduction to Databases 2/0/1/0.5
Introduction to database management systems. The relational data model. Relational algebra. Querying and updating databases: the query language SQL. Application programming with SQL. Integrity constraints, normal forms, and database design. Elements of database system technology: query processing, transaction management.
Pre-req: ECE345 or CSC190 or CSC192
AU: 100% ES

CSC401: Natural Language Processing 2/0/1/0.5
Introduction to techniques involving natural language and speech in applications such as information retrieval, extraction, and filtering; intelligent Web searching; spelling and grammar checking; speech recognition and synthesis; and multi-lingual systems including machine translation. N-grams, POS-tagging, semantic distance metrics, indexing, on-line lexicons and thesauri, markup languages, collections of on-line documents, corpus analysis. PERL and other software.
Pre-req: CSC207 or CSC209, STA247 or STA255 or STA257
AU: 100% ES

CSC420: Introduction to Image Understanding 2/1/0/0.5
Introduction to basic concepts in computer vision. Extraction of image features at multiple scales. Robust estimation of model parameters. Multiview geometry and reconstruction. Image motion estimation and tracking. Object recognition. Topics in scene understanding as time permits.
Pre-req: CSC263
AU: 100% ES

CSC444: Software Engineering 3/1.5/1/0.5
The software development process. Software requirements and specifications. Software design techniques. Techniques for developing large software systems; CASE tools and software development environments. Software testing, documentation and maintenance.
Pre-req: ECE344 or ECE353
AU: 50% ES, 50% ED

CSC485: Computational Linguistics 3/0/0/0.5
Computational linguistics and the processing of language by computer. Topics include: context-free grammars; chart parsing, statistical parsing; semantics and semantic interpretation; ambiguity resolution techniques; reference resolution. Emphasis on statistical learning methods for lexical, syntactic, and semantic knowledge.
Pre-req: STA247H1 or STA255H1 or STA257H1, CSC207H1 or CSC209H1

CSC486: Knowledge Representation and Reasoning 2/0/1/0.5
Representing knowledge symbolically in a form suitable for automated reasoning, and associated reasoning methods. Topics from: first-order logic, entailment, the resolution method, Horn clauses, procedural representations, production systems, description logics, inheritance networks, defaults and probabilities, tractable reasoning, abductive explanation, the representation of action, planning.

ECE356: Linear Systems and Control Theory 3/1.5/1/0.5
An introduction to dynamic systems and their control. Differential equation models of physical systems using transfer functions and state space models. Linearization. Initial and input response. Stability theory. Principle of feedback. Internal Model Principle. Frequency response. Nyquist stability. Loop shaping theory. Computer aided design using MATLAB and Simulink.
Pre-req: ECE355
AU: 75% ES, 25% ED

ECE358: Foundations of Computing 3/0/1/0.5
Fundamentals of algorithm design and computational complexity, including: analysis of algorithms, graph algorithms, greedy algorithms, divide-and-conquer, dynamic programming, network flow, approximation algorithms, the theory of NP-completeness, and various NP-complete problems. AU: 100% ES

ECE411: Real-Time Computer Control 3/1.5/1/0.5
Digital Control analysis and design by state-space methods. Introduction to scheduling of control tasks using fixed-priority protocols. Labs include control design using MATLAB and Simulink, and computer control of the inverted pendulum using a PC with real-time software.
Pre-req: ECE311 or ECE356
AU: 75% ES, 25% ED

ECE419: Distributed Systems 3/1.5/1/0.5
Design issues in distributed systems: heterogeneity, security, transparency, concurrency, fault-tolerance; networking principles; request-reply protocol; remote procedure calls; distributed objects; middleware architectures; CORBA; security and authentication protocols; distributed file systems; name services; global states in distributed systems; coordination and agreement; transactions and concurrency control; distributed transactions; replication.
Pre-req: ECE344 or ECE353
AU: 50% ES, 50% ED

ECE454: Computer Systems Programming 3/3/0/0.5

Fundamental techniques for programming computer systems, with an emphasis on obtaining good performance. Topics covered include: how to measure and understand program and execution and behaviour, how to get the most out of an optimizing compiler, how memory is allocated and managed, and how to exploit caches and the memory hierarchy. Furthermore, current trends in multicore, multithreaded and data parallel hardware, and how to exploit parallelism in their programs will be covered.

AU: 50% ES, 50% ED

ECE470: Robot Modeling and Control 3/1.5/1/0.5

Classification of robot manipulators, kinematic modeling, forward and inverse kinematics, velocity kinematics, path planning, point-to-point trajectory planning, dynamic modeling, Euler-Lagrange equations, inverse dynamics, joint control, computed torque control, passivity-based control, feedback linearization.

Pre-req: ECE311 or ECE356

AU: 25% NS, 75% ES

ECE532: Digital Systems Design 3/3/0/0.5

Advanced digital systems design concepts including project planning, design flows, embedded processors, hardware/software interfacing and interactions, software drivers, embedded operating systems, memory interfaces, system-level timing analysis, clocking and clock domains. A significant design project is undertaken and implemented on an FPGA development board.

Pre-req: ECE342 or ECE352

AU: 40% ES, 60% ED

ECE557: Systems Control 3/1.5/1/0.5

State-space approach to linear system theory. Mathematical background in linear algebra, state space equations vs. transfer functions, solutions of linear ODE's, state transition matrix, Jordan form, controllability, eigenvalue assignment using state feedback, observability, designing observers, separation principle, Kalman filters, tracking and the regulator problem, linear quadratic optimal control, stability. Laboratories cover the state space control design methodology.

AU: 75% ES, 25% ED

ECE568: Computer Security 3/3/0/0.5

As computers permeate our society, the security of such computing systems is becoming of paramount importance. This course covers principles of computer systems security. To build secure systems, one must understand how attackers operate. This course starts by teaching students how to identify security vulnerabilities and how they can be exploited. Then techniques to create secure systems and defend against such attacks will be discussed. Industry standards for conducting security audits to establish levels of security will be introduced. The course will include an introduction to basic cryptographic techniques as well as hardware used to accelerate cryptographic operations in ATM's and webservers.

Pre-req: ECE344 or ECE353

AU: 50% ES, 50% ED

MAT336: Elements of Analysis 3/0/1/0.5

This course provides the foundations of analysis and rigorous calculus for students who will take subsequent courses where these mathematical concepts are central of applications, but who have only taken courses with limited proofs. Topics include topology of Rn, implicit and inverse function theorems and rigorous integration theory.
Pre-req: MAT223 or MAT240, MAT235 or MAT237
AU: 100% MATH

MAT389: Complex Analysis 3/0/1/0.5

Course examines the following: analytic functions, Cauchy-Reimann equations, contour integration, Cauchy's theorem, Taylor and Laurent series, singularities, residue calculus, conformal mapping, harmonic functions, Dirichlet and Neumann problems and Poisson integral formulas. Course includes studies of linear differential equations in the complex plane, including Bessel and Legendre functions.
AU: 100% MATH

MIE457: Knowledge Modeling and Management 3/1/1/0.5

This course explores both the modelling of knowledge and its management within and among organizations. Knowledge modelling will focus on knowledge types and their semantic representation. It will review emerging representations for knowledge on the World Wide Web (e.g., schemas, RDF). Knowledge management will explore the acquisition, indexing, distribution and evolution of knowledge within and among organizations. Emerging Knowledge Management System software will be used in the laboratory.
Pre-req: MIE253, MIE350
AU: 100% ES

MIE566: Decision Analysis 3/0/2/0.5

The purpose of this course is to provide a working knowledge of methods of analysis of problem and of decision making in the face of uncertainty. Topics include decision trees, subjective probability assessment, multi-attribute utility approaches, goal programming, Analytic Hierarchy Process and the psychology of decision making.
Pre-req: MIE231H1 or MIE236H1 or equivalent
AU: 100% ES

ROB501: Computer Vision for Robotics 3/0/1/0.5

An introduction to aspects of computer vision specifically relevant to robotics applications. Topics include the geometry of image formation, basic image processing operations, camera models and calibration methods, image feature detection and matching, stereo vision, structure from motion and 3D reconstruction. Discussion of moving object identification and tracking as time permits.
Pre-req: CSC263
AU: 100% ES

STA302: Methods of Data Analysis I 3/0/0/0.5

Introduction to data analysis with a focus on regression. Initial Examination of data. Correlation. Simple and multiple regression models using least squares. Inference for regression parameters, confidence and prediction intervals. Diagnostics and remedial measures. Interactions and dummy variables. Variable selection. Least squares estimation and inference for non-linear regression.
Pre-req: STA248 or STA255 or STA261 or ECO227
AU: 100% MATH

STA410: Statistical Computation 3/0/0/0.5

Programming in an interactive statistical environment. Generating random variates and evaluating statistical methods by simulation. Algorithms for linear models, maximum likelihood estimation, and Bayesian inference. Statistical algorithms such as the Kalman filter and the EM algorithm. Graphical display of data.

Pre-req: STA302, CSC108 or CSC120 or CSC121 or CSC148

AU: 100% MATH

Appendix C: Foundation Curriculum

<u>1F Semester</u>
- *Structures and Materials – An Introduction to Engineering Design* introduces properties of various structures and materials, as well as their use.
- *Praxis I* requires students to address on-campus design challenges through hands-on activities and presentations.
- *Classical Mechanics* gives an understanding of Newtonian mechanics, and considers the interactions which influence motion in terms of force, momentum and energy.
- *Engineering Mathematics and Computation* bridges high school and university mathematics, and makes connections to the "engineering point of view."
- *Calculus I* is the first course in a series of calculus courses found in the first 2 years, and includes theory and application of differential and integral calculus.
- *Introduction to Computer Programming* provides a well-rounded understanding of programming theory and application, using Python as the programming language.

<u>1S Semester</u>
- *Molecules and Materials* provides fundamentals of molecular chemistry as it relates to the properties of materials.
- *Linear Algebra* provides an understanding of linear systems and matrix algebra and their applications in engineering.
- *Calculus II*, a continuation from the course in first semester, offers a more advanced exploration into the subject, including multivariable functions and partial derivatives.
- *Fundamentals of Electric Circuits* focuses on the theory and application of electric circuits.
- *Computer Algorithms and Data Structures*, the second semester of computer programming, builds on the foundations introduced in the fall semester, using Python and C.
- *Praxis II* requires students to address design challenges facing the City of Toronto through hands-on activities and presentations.

<u>2F Semester</u>

- *Ordinary Differential Equations* focuses primarily on ordinary differential equations and includes a computational component.
- *Vector Calculus & Fluid Mechanics* emphasizes vector calculus as the mathematical language of fluid mechanics.
- *Digital and Computer Systems* provides an understanding of digital system design principles and represents the technology component for the semester.
- *Waves and Modern Physics* provides an introduction to the basic ideas of classical statistical mechanics and radiation, with applications to experimental physics.
- *Thermodynamics and Heat Transfer* explores classical thermodynamics and its applications to engineering systems, and is paired with the study of heat transfer.
- *Engineering and Society* examines the interrelations of science, technology, society and the environment.

- *Engineering Design* presents a full mechatronics design experience through the construction of functional autonomous robot.
- *Probability and Statistics* completes the mathematical studies in the foundation curriculum.
- *Quantum and Thermal Physics* completes the strong physics component in the foundation years.
- *Electromagnetism* provides an understanding of electromagnetic phenomena.
- *Biomolecules and Cells* introduces concepts in cell biology and physiology, and demonstrates the use of biological understanding in engineering applications.
- Complementary Studies Elective provides an opportunity to explore an area of interest outside of engineering.

Appendix D: Degree Level Outcomes

Degree Level Expectations and Outcomes for Graduates Receiving the Degree of Bachelor of Applied Science in Engineering Science

Faculty of Applied Science and Engineering
University of Toronto

April 8, 2008

Program Objectives and Requirements

1.1 Program Objectives

The Engineering Science program aims to provide all of its undergraduate students with an education that will encourage them to be responsible global citizens, future leaders in society, and leading practitioners of the engineering sciences.

The Engineering Science Program-Level Objectives Include:

➢ *To provide an academically enriched program for young men and women seeking a significant academic challenge;*

➢ *To produce engineering science graduates who have a deep understanding of mathematics, physics, chemistry, biology and the engineering sciences, and can apply and integrate this knowledge to solve complex problems;*

➢ *To prepare men and women for careers in the engineering sciences within academia, industry and the public sector as well as careers in other professions;*

➢ *To produce engineering science graduates who have an understanding of the impact of technology on individuals, groups and society-at-large;*

➢ *To educate men and women as global citizens and leaders of the society in which they live and work.*

1.2 Requirements to Graduate

In order to graduate with a Bachelor of Applied Science in Engineering Science, each student must complete a full undergraduate program in Engineering Science as outlined in the Faculty Calendar within nine calendar years of first registration, exclusive of mandatory absences from his/her program.

Students must satisfy both the requirements associated with being an accredited engineering program and the requirements associated with the degree program itself.

1.2.1 Accreditation Requirements

The practice of engineering is regulated, by statute, in all Canadian provinces and territories. To become a Professional Engineer, an individual must satisfy the requirements of the licensing bodies. These requirements include a degree from an accredited program, successful completion of a professional practice examination in engineering law and ethics, and suitable experience.

The Engineering Science program is an accredited engineering program and is evaluated regularly by the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers.

The criteria set out by the CEAB are designed to ensure that each graduate has a foundation in Mathematics and Basic Sciences, a broad preparation in Engineering Sciences and Engineering Design and an exposure to non-technical subjects (Complementary Studies) that complement the technical aspects of the curriculum[1].

1.2.2 Program-Level Requirements

All students in the Engineering Science program are required to complete two foundation years and two specialization years. Specific outcomes for these components of the program will be described later in the document in Section 3.

There are a set of program-level requirements, described below, that apply to all Engineering Science students:

1. **Coursework:** Engineering Science students participate in a common foundation curriculum (years 1 & 2), designed for and delivered only to students in the Engineering Science program. Courses in the foundation curriculum are taught at an accelerated pace with a focus on developing the students' ability to derive results using a first principles approach. Many of the courses in the specialization curriculum (years 3 & 4) are taught in a similar fashion and build on the unique background developed in the foundation curriculum.

    a. Foundation Curriculum (years 1&2):

      - Theoretical and Applied Physics, Chemistry & Applied Chemistry and Engineering Biology;
      - Pure and Applied Mathematics;
      - Engineering Science & Technology;
      - Engineering Design, Professional Practice & Issues-based Education.

    b. Specialization Curriculum (years 3&4):

      - Courses in an area of specialization, several of which are offered only to Engineering Science students, building on their unique foundation experience;
      - Technical Electives, which provide students with choice;
      - Courses with substantial design content relevant to the area of specialization.

    c. Complementary Studies Electives.

    d. A basic knowledge of Engineering Economics.

    e. Across all four years, sufficient opportunities for the development of professional awareness and practice.

2. **Research:** All students participate in an independent research thesis project in their fourth year.

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[1] Engineers Canada, "Accreditation Criteria and Procedures: Canadian Engineering Accreditation Board", Canadian Council of Professional Engineers, ISSN 1708-8054 (2007)

3. **Promotion:** Engineering Science consists of eight Fall (F) and Winter (W) Sessions taken in order.

   a. A unique set of promotion rules exist in the first year for Engineering Science students to enable them to adapt to the rigors of the program:

      i. Students must achieve a sessional average of 55% or greater to continue in Engineering Science after the 1F semester.
      Students with an average <55% must transfer to another engineering program.

      ii. Students must achieve a sessional average of 65% or greater to continue in Engineering Science after the 1W semester. Students with an average <65% but must transfer to another engineering program.

   b. To gain credit for a session a student must:

      i. satisfy the academic regulations to proceed to the succeeding session as described in the Faculty Calendar, and

      ii. not be subsequently required to repeat the session for which credit is to be gained, and

      iii. achieve a course mark of 50% or greater in every course taken as part of the academic load in a session, and

      iv. not have any outstanding designations of 'standing deferred', 'incomplete' or 'No Grade Available' for any course in any session.

   c. To be eligible to graduate, each student must attain a weighted Session Average of 60% or greater in the final session of their program. Any student who does not achieve a weighted Session Average of 60% in their final session (4W), but has attained a weighted Session Average that allows them to proceed to the next session on probation, shall repeat the final session and achieve a weighted Session Average of 60% or greater to graduate.

4. **English Proficiency:** Each student must show an ability to write English coherently and correctly in all written work submitted for evaluation. Consequently, the Faculty reserves the right to ask each student to write a post-admission English Proficiency Assessment at the beginning of his or her first year of studies. Every student will also take at least one course that includes a written communication component within their curriculum. Satisfactory completion of the course or courses is required for graduation.

5. **Professional Experience:** The Faculty requires that all students complete a minimum of 600 hours of practical work before graduation.

Degree Level Expectations for the Bachelor of Applied Science in Engineering Science

2.1   Depth and Breadth of Knowledge

Students in the Engineering Science program participate in a comprehensive, two-year foundation curriculum. This foundation forms a common basis for study across various areas of specialization, as well as future study or work in engineering, mathematics or science, and also provides students with a developed knowledge and critical understanding of engineering, science and engineering science.

Specific outcomes include:

- An understanding of the formative theories that underlie the functioning of our universe;
- Knowledge of problems and challenges that sit at the intersection of science and engineering;
- A comprehensive understanding of science including biology, chemistry and physics;
- A comprehensive understanding of a broad range of the engineering sciences, including dynamics and mechanics, materials science, electric circuitry, thermodynamics, fluid mechanics, transport phenomena, digital and computer systems, chemical kinetics, and electromagnetism.
- A comprehensive understanding of mathematics in its pure and applied form;
- Knowledge and practice in engineering design, laboratory and communication;
- Knowledge of a breadth of design methodologies.

Upon completion of the two-year foundation curriculum, students participate in one of eight areas of specialization through years 3 and 4. Students develop depth of knowledge through outcomes that include:

- Ability to identify major research areas within an area of specialization;
- Demonstrate how their area of specialization intersects with other engineering science disciplines;
- Synthesize information and theories to conceptualize new engineering challenges;
- Carry out original research within their area of specialization;
- Demonstrate an awareness of new and emerging technologies;
- Apply fundamental knowledge from the foundation years.

The program consists of a complementary studies component that students participate in across all four years. This requirement allows students to develop critical thinking and analytical skills outside of engineering science.

2.2   Knowledge of Methodologies

Core methodologies within the Engineering Science program include engineering design and experimental science. Engineering Science students demonstrate the following outcomes:

Engineering Design:

- Identify and conceptualize engineering problems, including the identification of constraints;
- Analyze the design work of established engineers;
- Apply a deep understanding of pure math and science to engineering problems;
- Design a system, component or process to meet desired needs within economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability;
- Evaluate the appropriateness of various approaches to analyze and solve a design problem;
- Devise and sustain arguments for their design;
- Function as a member of a design team;

- Manage the design process and evaluate outcomes;
- Understand how technology impacts society at the individual, community and global level.

Experimental Science:

- Practice the scientific method;
- Practice research methodologies specific to one's area of specialization;
- Connect knowledge of pure math, science and engineering science to an experimental setting;
- Design and conduct experiments;
- Collect, analyze and interpret data;
- Conduct error analysis;
- Develop skills in research methodologies specific to one's area of specialization;
- Work as a member of a research team.

2.3   Application of Knowledge

The application of engineering science to solve engineering problems is fundamental to the Engineering Science program. Students are also required to demonstrate an understanding of their professional and ethical responsibility to society, and apply this understanding to design projects. Specific outcomes include:

- Acquire knowledge necessary to complete research and design work;
- Apply established theoretical information and past research results to a scientific or engineering problem;
- Analyze the impact of engineering projects on the environment and society.

2.4   Communication Skills

The Engineering Science Program requires students to demonstrate a number of outcomes related to communication skills, through a communication component placed within the design curriculum. Specific outcomes include:

- Understand that communication is integral to engineering practice;
- Communicate information to specialist and non-specialist audiences;
- Present outcomes of research and design through oral presentations;
- Present outcomes of research and design through technical writing;
- Present outcomes of research and design through visual communication;
- Demonstrate point of view through persuasive writing and debate;
- Comprehend and discuss the impact of the engineering profession in a global and societal context;
- Comprehend and discuss contemporary issues.

2.5   Awareness of Limits of Knowledge

Engineering Science students in their chosen area of specialization develop a deep understanding of a discipline within engineering science as it is currently appreciated by educators, who are at

the same time involved in original scholarship in the subject area. The course content is designed, in part, to provide students with an appreciation of the uncertainties, ambiguities and limitations of knowledge in the specific area. Specific outcomes include:

- An awareness of research within a particular discipline;
- An awareness of the questions that remain and the barriers that exist to answering these questions within a particular discipline;
- An appreciation of the limits of one's knowledge, and how the boundaries of knowledge limit action.

2.6   Autonomy and Professional Capacity

Engineering Science students are required to develop an awareness of the engineering profession and the skills and qualities of professional practice. Specific outcomes include:

- An ability to work in teams, recognizing the contributions of others and one's own responsibility in a team-based setting;
- Decision-making skills in engineering design and research;
- An understanding of the value of acknowledging the work of others;
- An understanding of ethical behaviour, particularly as it relates to engineering projects;
- An ability to manage one's learning and learning needs;
- Life-long learning skills.

2.7   Other Degree Level Expectations

The Engineering Science program requires all students to develop an advanced understanding of how to obtain, manipulate and evaluate information and bring diverse sources together to develop a comprehensive understanding of specific issues, solve problems or apply the scientific method to create further knowledge in the discipline.