Michigan Tech

Office Memo

Office of the Provost and
Senior Vice President for Academic Affairs

Phone: (906) 487-2440
Fax: (906) 487-2935

TO: Richard Koubek, President

FROM: Jacqueline E. Huntoon, Provost & Senior Vice President for Academic Affairs

DATE: March 27, 2020

SUBJECT: Senate Proposal 25-20

Attached is Senate proposal 25-20, "Bachelor of Science in Robotics Engineering," and a memo stating the Senate passed this proposal at their March 25, 2020 meeting. I have reviewed this memo and recommend approving this proposal.

I concur X do not concur_______ with this recommendation.

Richard Koubek, President

Date 03/30/2020

Michigan Tech

University Senate

DATE:	March 26, 2020
TO:	Richard Koubek, President
FROM:	Michael Mullins University Senate President
SUBJECT:	Proposal 25-20
COPIES:	Jacqueline E. Huntoon, Provost & Senior VP for Academic Affairs

At its meeting on March 25, 2020, the University Senate approved Proposal 25-20, "Bachelor of Science in Robotics Engineering". Feel free to contact me if you have any questions.

The University Senate of Michigan Technological University
Proposal 25-20

(Voting Units: Academic)

(Follows Senate Procedure 108.1.1)

"Bachelor of Science in Robotics Engineering"

Date: October, 2019

Contact: Glen Archer, Interim Chair, Electrical and Computer Engineering
Leonard Bohmann, Associate Dean College of Engineering

1. General Description and Characteristics of Program:

The Department of Electrical and Computer Engineering within the College of Engineering proposes the establishment of a Bachelors of Science in Robotics Engineering program.

The addition of this program fills a gap in Michigan Tech's program offerings that currently exists between the electrical engineering, mechanical engineering, and computer science program offerings. Robotics engineering is the application of these disciplines to automation design, in manufacturing as well as other areas of human endeavor.

Program Educational Objectives (required for ABET accreditation; ABET EAC criterion 2)

We expect the early career graduates of this program to:

1. be successful in applying their knowledge and skills in robotics engineering in finding creative solutions to engineering problems involving robots or robotic systems, in an industrial or research and development setting, as evidenced by becoming a team/group leader or by earning a first promotion by their employer, **OR**,
2. leverage their engineering analysis and design capabilities so as to develop a skill set for successful technical, professional, and/or entrepreneurial leadership positions, as evidenced by advanced technical certification, an advanced technical or professional degree, or starting a business.

By the end of the program students will be able to work with and design robotic systems. The Student Outcomes associated with the program consist of the following: (ABET EAC criterion 3). These are outcomes attained by the time of graduation.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

In addition to the student outcomes mandated by ABET Engineering Accreditation Commission listed above, this program will also satisfy the Michigan Tech Undergraduate Student Learning Goals. The ABET student outcomes are highly congruent with MTU's student learning goal, though they do not necessarily map one-to-one.

Disciplinary Knowledge Students demonstrate a depth of knowledge in one area/ discipline, as well as a breadth of knowledge that (1) enables adaptability and flexibility as knowledge grows and changes, and (2) recognizes linkages/complementarity to other areas/disciplines. This objective will be fulfilled through student mastery of the skills and knowledge acquired in the electrical engineering, mechanical engineering, computer science and cognitive and learning science curriculum that provides the theoretical and technical foundation of the program.

Knowledge of the Physical and Natural World This learning goal is accomplished by studying mathematics and the physical and natural sciences. Mathematics courses are responsible for "Interpretation of Mathematical Representations" and "Assumptions" and should contribute to the others as appropriate. Science courses are responsible for "Data Analysis", "Scientific Knowledge", and "Proposes Solutions/Models/Hypotheses" and should contribute to the others as appropriate. ABET requires 30 Cr of math and basic sciences and they are fulfilled by this degree program.

Global Literacy A globally literate student will demonstrate the ability to understand and analyze issues on multiple scales and from diverse perspectives, acknowledging interconnectivity and complexity. As globally literate, students should 1) become informed and open-minded people who are attentive to diversity across the spectrum of differences, 2) seek to understand how their actions affect the human and natural world on multiple scales, and 3) address the world's most pressing and enduring issues while considering context, complexity, and interconnectivity. This learning goal begins in UN1015 and is further developed in UN1025, additional coverage culminates in EE/MEEM 3901 and Capstone Design.

Critical and Creative Thinking Students will be able to think critically and creatively, as demonstrated by their broad, adaptable and versatile use of reasoning, logic, and evidence to access and evaluate information and solve complex problems both independently and in groups. This process will begin in UN1015, UN1025 and be further developed as the student proceeds through the math sequence and begins to develop an algorithmic perspective through coding exercises. The ultimate expression of the success of this goal will be the student's ability to successfully negotiate their capstone design experience.

Communication Students will be able to communicate effectively, orally, in writing and in new media, to a wide variety of audiences**.**

Written communication is the development and expression of ideas in writing. Written communication involves learning to work in many genres and styles. It can involve working with many different writing technologies, and mixing texts, data, and images. Written communication abilities develop through iterative experiences across the curriculum. This is also addressed by ABET Student Outcome 3.

Oral communication is a prepared, purposeful presentation designed to increase knowledge, to foster understanding, or to promote change in the listeners' attitudes, values, beliefs, or behaviors. Oral communication abilities develop through iterative experiences across the curriculum. This is also addressed within the required technical curriculum by ABET Student Outcome 3.

Information Literacy Students will be able to analyze the need for, strategically access, critically evaluate, and use information effectively, ethically, and legally. This is addressed within the required technical curriculum through ABET Student Outcomes 4 and 7.

Technology Students will demonstrate knowledge of technology and its implications in society, and be able to design and/or use technology for creative activities or innovative solutions to problems. This is also addressed within the required technical curriculum through ABET Student Outcome 2.

Social Responsibility and Ethical Reasoning Students will be able to identify and address conflicting ethical values and develop a sense of responsibility for the broad impacts of individual actions and social institutions. They will understand their role as citizens and their responsibility to work with others in promoting quality of life and a sustainable society. Social responsibility, like civic engagement, means promoting the quality of community life through both political and non-political processes. Ethical reasoning is reasoning about right and wrong human conduct. These qualities are fundamental to the profession of engineering. This is also addressed within the required technical curriculum through ABET Student Outcome 4.

2. Rationale:

The BS in Robotics Engineering, as one of the degree programs in the Department of Electrical and Computer Engineering is proposed for these reasons:

1. The use of robotics is increasing, driving the need for Robotics Engineers.
2. Students are asking for it.
3. There are jobs for graduates.
4. Electrical and Computer Engineering has the current capacity to offer this program.

The growth of the robotics industry is creating a demand in engineering talent to commercially exploit advances in robotics to design robotic systems. According to the International Federation of Robotics [1], sales of robots increased 30% in 2017 worldwide. In the United States it was 6%. While this is strong growth, there are indications that there is a growing need in the US and the need for robotic engineers is predicted to strongly increase. The US ranked 7th on the list of countries with the highest number of industrial robots per 10,000 employees in non-automotive manufacturing facilities at 117. We have a long way to go to catch up with South Korea, which is at the top of the list with 553 industrial robots per 10,000 employees.[1]

Many prospective students and their parents have asked repeatedly about robotics and our robotics program when they come to tour campus. This is an outgrowth of the many robotics education programs developed for primary and secondary school children, the most successful being FIRST Robotics. These are some of the quotes from Michigan Tech regional recruiting staff when asked about this:

- YES! I do think a degree in Robotics Engineering would be helpful for recruiting purposes.
- I think it would be a great thing to add! I've gotten numerous students who ask specifically about robotics engineering
- I vote "yes"! More like, "yes, please!" When someone at a college fair or in a HS visit asks if we have robotics engineering (and it happens a few times a week during travel), I have to say "no, but ... ")
- I say YES on a robotics engineering degree. I have looked at Lawrence Tech's robotics degree in the past and we already have a lot of classes in place compared to their degree.

[1] *Executive Summary World Robotics 2018 Industrial Robots*, International Federation of Robotics, https://www.ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf , [accessed April 1, 2019].

Objective data on robotics engineer jobs is difficult to obtain as this job title is not tracked by the US Bureau of Labor Statistics. One source is the placement data for the oldest and largest Robotics Engineering program in the country, that at Worcester Polytechnic Institute [2]. That program had a 95.5% placement rate with a starting salary of $78,300.

[2] *WPI Post Graduation Report, Class of 2018*, Worcester Polytechnic University, https://www.wpi.edu/sites/default/files/CDC_StatReport_2018-0df4039c14a2435284634b804fb3 2241.pdf, [accessed April 1, 2019].

3. Related Programs:

At Michigan Tech

Robotics Engineering encompasses some aspects of the disciplines of electrical engineering, mechanical engineering, and computer science. As such, parts of this program are related to the following programs: (1) the B.S. in Electrical Engineering (2) B.S. in Electrical Engineering Technology, (3) B.S. in Mechanical Engineering, (4) B.S in Mechanical Engineering Technology, (5) the B.S. in Computer Science, (6) B.S. in Computer Networks and Systems Administration, and (7) the B.S. in Cognitive and Learning Science. But none of these programs contain all of Robotics Engineering, and employers seek this specialized degree because of the training of its graduates. The growth in the Robotics Engineering program at WPI relates to this fact, described later.

This program is most like the Bachelor of Science in Mechatronics currently proposed by the MERET division in the College of Computing. There are notable differences in these two programs. The Mechatronics degree offers a deep understanding of the application of mechatronic systems in an industrial or manufacturing setting, the “how” of mechatronics. The Robotics Engineering degree functions at a different level of abstraction, the “why” of robots and autonomous machines in other settings, including autonomous vehicles. And, the "how" of how we interface robots with other systems, in a congruent manner, using the language of the associated engineering disciplines of mechanical engineering, computer engineering, and electrical engineering. This program is more theoretical with a stronger emphasis on the underlying mathematics.

The proposed BS in Robotics Engineering meets the requirements to be accredited as an engineering program through the ABET Engineering Accreditation Commission under the program criteria for engineering (without modifiers), general engineering, engineering physics, engineering science and similarly named engineering programs. Table 5.1 shows that a sample 8-semester plan for the Bachelor of Science in Robotics Engineering satisfies the standards described in ABET's Criterion 5 Curriculum by requiring 31 semester credit hours of mathematics and basic sciences. The minimum is 30 semester credit hours. The Bachelor of Science in Robotics Engineering also requires 68 semester credit hours of engineering topics appropriate to the program. The ABET minimum for engineering topics is 45 semester credit hours. The difference between the minimum and the BSRE program requirement is driven by the prerequisite chains, and illustrates the robustness of the program relative to ABET, EAC (Engineering Accreditation Criteria). What this means in a practical sense, is that on our first accreditation cycle, Robotics Engineering will strongly satisfy the minimum requirement of 45 credit semester hours of engineering topics.

In Michigan

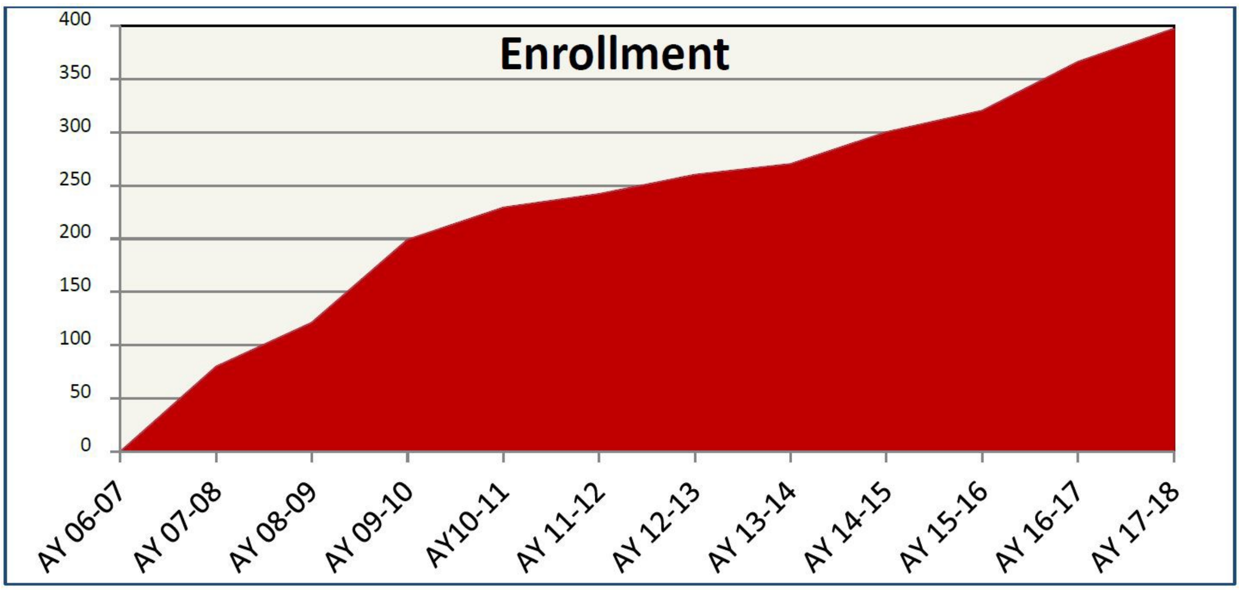
There are three bachelors level Robotics Engineering degree programs in Michigan. The program at Lawrence Technological University was accredited by ABET in 2014. The other two are at the University of Michigan - Dearborn, which started in 2014, and Lake Superior State University, which started in 2018. It appears that both programs are working toward ABET accreditation. Lake Superior State is accredited through ABET Engineering Technology Accreditation Commission (ETAC), one of the four ABET commissions (EAC, ETAC, ANSAC, and CAC, corresponding to Engineering Accreditation Commission, Engineering Technology Accreditation Commission, Applied Natural Sciences Accreditation Commission, and Computing Accreditation, respectively).

The program at Lawrence Tech is 136 credit hours, substantially more than this proposed program, and has a little more mechanical engineering content than the program being proposed. The program at the UM - Dearborn requires 125 credit hours and has a little more electrical engineering content than the program being proposed. The program at Lake Superior State requires 124 credits and has significantly less content in the area of microprocessor integration than this proposed program. Thus, the proposed program at MTU represents a strong balance within the state between mechanical engineering content, electrical engineering content, and microprocessor integration and comes in at a total credit hour balance of 123 to 124 credits.

In the United States

Surprisingly, there are only a few ABET EAC accredited Robotics Engineering degree programs in the United States. Outside of Michigan there are two accredited programs, one at Gannon University and the other at Worcester Polytechnic Institute (WPI), a well-known and reputable program. There are at least four others. Two appear to be working toward ABET accreditation, the programs at Southern Illinois University at Edwardsville and at University of California, Santa Cruz. The other two programs are at Widener University in Pennsylvania and Johnsons & Wales University in Rhode Island.

The program at WPI is the oldest and largest Robotics Engineering program in the country. The program started in 2007 and was the subject of a retrospective paper at the 2018 ASEE conference [3]. It has a robust curriculum and it is one that we studied closely in developing our own. Students have been attracted to the program and its enrollment has built up to about 400 students as shown in the figure below. Note that the trendline is still increasing. Many students who would have otherwise selected Michigan Tech may have enrolled at WPI for this offering.



Enrollment in WPI's Robotics Engineering degree program [3]

[3] Michael A. Gennert and Craig B. Putnam, "Robotics as an Undergraduate Major: 10 Years' Experience," in *125 ASEE Annual Conference and Exposition*, Salt Lake City, UT, June 24-27, 2018, paper # 23299, https://www.asee.org/public/conferences/106/papers/23299/view, [accessed April 1, 2019].

4. Projected Enrollments:

It is expected that approximately 40 - 45 students per year by 2025 will earn this degree, with an enrollment of approximately 250 students by fall, 2025. As enrollment grows, new faculty and teaching assistants will be needed in support of the program.

5. Curriculum Design: (New courses in **Boldface**) The curriculum is further described in Table 5.1

Major Requirements

Mathematics and Science

(15 credits satisfy the General Education STEM requirement)

CH 1150 University Chemistry 1 (3 cr.) (MA 1160(C))

CH 1151 University Chemistry Lab 1 (1 cr.) (MA 1160(C), corequisite: CH 1150)
MA 1160 Calculus with Technology 1 (4 cr.)
MA 2160 Calculus with Technology 2 (4 cr.) (MA 1160)
MA 2320 Elementary Linear Algebra (2 cr.) (MA 1160)
MA 3160 Multivariable Calculus with Technology (4 cr.) (MA 2160)
MA 3520 Elementary Differential Equations (2 cr.) (MA 2160, MA 2320)
PH 1100 Physics by Inquiry 1 (1 cr.) (MA 1160(C))
PH 1200 Physics by Inquiry 2 (1 cr.) (PH 1100)
PH 2100 University Physics 1 - Mechanics (3 cr.) (MA 1160, PH 1100(C))
PH 2200 University Physics 2 - Electricity and Magnetism (3 cr.) (MA 2160, PH 1200(C), PH 2100)

Mathematics or Science elective (3 cr.)

Robotics Engineering courses

SAT2711 Linux Fundamentals (4 cr.)
EE 2180 Introduction to Robotics (3 cr.)
EE 2174 Digital Logic and Lab (4 cr.) (CS 1111)
EE 3010 Circuits and Instrumentation for Cyber Physical Systems (3 cr.)
EE 3160 Signals and Systems (3 cr.) (**EE 3010**, MA 2320, MA 3520)EE/EET 3373
Introduction to Programmable Logic Controllers (3 cr.) (EE 3010)
EE 3901 Design Fundamentals (2 cr.) (EE 3171, UN 1015)
EE3280 Robot Operating Systems (3cr) (EE2180)
ENG 1101 Engineering Analysis and Problem Solving (3 cr.) (MA 1160(C))
ENG 1102 Engineering Modeling & Design (3 cr.) (MA 1160, ENG 1101)
ENG 2120 Statics - Strength of Materials (4 cr.) (ENG 1102, MA 2160, PH 2100)
MEEM 2700 Dynamics (3 cr.) (ENG 2120, MA 3160(C), PH 2100)
MEEM 3400 Mechanical System Design and Analysis (3 cr.) (**ENG 2120)**, MEEM 2700)

Embedded Systems course (choose 1, 4 cr.)
EE 3171 Microcontrollers for Cyber-Physical Systems (4 cr.) (EE 2174, EE 3010)
OR
EET 4141 Microcontroller Interfacing (4 cr.) (**EET 2141 or CS 1121 or CS 1111?**)

System dynamics course (choose 1, 3 - 4 credits)
EE 3261 Control Systems (3 cr.) (EE 3160)
OR
MEEM 3750 Dynamic Systems (4 cr.) (MEEM 2700, MA 3520)

Robotic Engineering Technical electives (choose 2 sets, 4 cr.)
EE 4219 Introduction to Electric Machinery and Drives (3 cr.) (**EE 3010**)
EE 4220 Introduction to Electric Machinery and Drives Lab (1 cr.) (EE 4219(C))
OR
EE 4375 Autonomous Vehicle Design (4 cr.) (EE 3261)
OR
MEEM 4705 Robotics and Automation (4 cr.) (MEEM 3750)

OR
EE/EET 4373 Advanced Programmable Logic Controllers (4 cr.) (EE 3373)
OR
EE/MEEM 4800 Actuation and Articulation (3cr)

Robotic Engineering electives (choose 1, 3 cr.)
HU 3710 Engineering Ethics (3 cr) (UN 1025 and (UN1025 or Modern Language -3000 level or higher)
PSY3850 Human Factors Psychology (3 cr)
PSY 3860 Human Performance (3 cr) PSY2000
PSY 4010 Cognitive Psychology (3 cr) PSY2000
PSY 4160 Sensation and Perception (3 cr) BL 1040 or BL1020

Capstone Design (choose 1 group, 4 - 6 cr.)
EE 4901 EE Design Project 1 (2 cr.) (**EE 3171**)
EE 4910 EE Design Project 2 (2 cr.) (EE 4901)
OR
MEEM 4901 Senior Capstone Design 1 (2 cr.) (permission)
MEEM 4911 Senior Capstone Design 2 (2 cr.) (permission)
OR
with permission of the Robotics Engineering program for work on robotics related project
ENT 3950 Enterprise Project Work 3 (1 cr.)
ENT 3960 Enterprise Project Work 4 (1 cr.)
ENT 4950 Enterprise Project Work 5 Capstone (2 cr.)
ENT 4960 Enterprise Project Work 6 Capstone (2 cr.) (ENT 4950)

General Education Requirements (24 cr.)
Core: 12 Credits
HASS: 12 Credits
Mathematics and Science requirements are satisfied within the Major Requirements

Total Credits required 123 - 124

Table 5.1 -- ABET Engineering Accreditation Commission Analysis of Math and Basic Sciences and Engineering topics appropriate to the program

Table 5.1 Robotics Engineering Curriculum					

Course	Title	Indicate whether the course is required, elective or a selective elective by and R, E, SE	Math & Basic Science	Discipline Specific Topics	General Education
Semester 1					
CS1111	Intro to Programming in C/C++	R		3	
ENG1101	Engineering Analysis	R		3	
MA1160/61	Calculus with Technology 1	R	4		
UN1015	Composition	R			3
	Soc Resp/Ethical Reasoning course	SE			3
Semester 2					
CH1150&1151	Univ. Chemistry I & Lab I	R	4		
CH1153	*Prob solv chem I (optional) 1Cr*	E			
ENG1102	Engineering Modeling & Design	R		3	
MA2160	Calculus with Technology 2	R	4		
UN1025	***Global Issues***	R			3
Semester 3					
MA2320	Elementary Linear Algebra	R	2		
EE2174	Digital Logic and Verilog Programming	R		4	
PH1100	Physics by Inquiry 1	R	1		
PH2100	Univ. Physics 1- Mechanics	R	3		
SAT2711	Linux System Fundamentals	R		4	
	Critical/CreativeThinking course	E			3
Semester 4					

MA3520	Elementary Differential Equations	R	2		
EE3010	Circuits and Instrumentation for CPS	R		3	
EE2180	Introduction to Robotics	R		3	
ENG2120	Statics-Strength of Materials	R		4	
Ph1200	Univ Physics II Electricity and Magnetism	R	1		
PH2200	Univ Physics II Electricity and Magnetism	R	3		
Semester 5					
MA3160	Multivariable Calculus	R	4		
MEEM2700	Dynamics	R		3	
EE3160	Signals and Systems			3	
EE3171 **OR** EET4141	Microcontrollers for CPS OR Microcontroller Interfacing	SE		4	
	HASS EC/PSY/SS Elective	E			3
Semester 6					
EE3901	Design fundamentals	R		2	
MEEM 3400	Mechanical Systems Design & Analysis	R		3	
EE3261 OR MEEM3750	Control systems OR Mech sys Design OR Dynamic Systems **(4 Cr)**	SE		3	
EE3280	**Robot Operating Systems**	R		3	
	Math/Science Elective	E	3		
Semester 7					
EE/MEEM49011	Design Project 1	R		2	
EE/EET3373 Robotics Engineering Approved Elective	Intro to Programmable Logic Controllers	SE		3	
	Robotics Engineering Approved Elective	SE		3	

EE4235	Sensing and Processing in Robotic Applications	R		3	
	HASS Composition/Communication	R			3
Semester 8					
EE/MEEM4910	Design Project 2	R		2	
EE4219&4220 **OR** EE4373 **OR** MEEM4750 **OR** EE4375 **OR** EE/MEEM4800	Electric Machinery & Drives &Lab **OR** Advanced PLCs **OR** Robotics and Mechatronics **OR** Autonomous Vehicle Design **OR** Actuation and Articulation	SE		4	
	EE/MEEM Tech Elective	SE		3	
	HASS Elective	E			3
	HASS HU/FA Elective	E			3
		Total	**31**	**68**	**24**
ABET requirements are satisfied? Yes.	Minimum Requirements ABET Engineering Accreditation Commission		**30**	**45**	
				Total Cr	**123**

6. New Course Descriptions:

EE 2180 Introduction to Robotics (3 cr.)
An introduction to the principles of designing and using robots and autonomous systems to solve engineering problems. Topics include basic robot kinematics, control strategies, sensing, perception, path planning, the "see-think-act" cycle and functional safety. Class involves hands on team-projects with final project competition. (prereq MA1160)

EE3280 Robot Operating Systems (3cr)
Basics of ROS, creating and debugging of ROS programs, Linux environment, Gazebo simulation environment and scripting

EE4532 Sensing and Processing for Robotic Applications (3cr)
Sensing modes, signal and image processing for industrial robotics automation processes. Emphasis placed on widely used sensors, including cameras and 3-D sensors for process control and computer vision for autonomous navigation. (prereq EE3160)

EE4375 Autonomous Vehicle Design (4 cr.)

Course covers the design of autonomous vehicles including the interplay of autonomous capability level and the number and placement of sensors and computing requirements. Specific focus on autonomous vehicle sensors, architectures, control systems, and functional safety. Students will work with autonomous vehicle data sets to develop sensing, perception, and path-planning algorithms. Students will also develop autonomous vehicle control system in simulation. (prereq EE 3261)

EE/MEEM 4800 Actuation and Articulation
Advanced topics in robotic actuator design, emerging actuator technologies, actuator kinematic design, forward and inverse modeling.(3 Cr) (EE3261 or MEEM3750)

Link to robotics related coursework taught in College of Engineering
(in ECE, ME-EM and in MSE)

7. Model schedule

Courses in **bold** are new courses

	Semester 1	
CS1111	Intro to Programming in C/C++	3
ENG1101	Engineering Analysis	3
MA1160/61	Calculus with Technology 1	4
UN1015	Composition	3
	Soc Resp/Ethical Reasoning course	3
	Total	***16***

	Semester 2	
CH1150&1151	Univ. Chemistry I & Lab I	4
CH1153	*Prob solv chem I (optional)*	*1*
ENG1102	Engineering Modeling & Design	3
MA2160	Calculus with Technology 2	4
UN1025	Global Issues	3
	Total	***14/15***

	Semester 3	
MA2320	Elementary Linear Algebra	2
EE2174	Digital Logic w/ Lab	4
PH1100	Physics by Inquiry 1	1
PH2100	Univ. Physics 1- Mechanics	3
SAT2711	Linux system Fundamentals	4
	Critical/CreativeThinking course	3
	Total	***17***

Semester 4

MA3520	Elementary Differential Equations	2
EE3010	Circuits and Inst. for CPS	3
EE2180	**Intro to Robotics**	3
ENG2120	Statics - Strength of Materials	4
PH1200 &2200	Univ Physics II Elec & Magnetism	4
	Total	***16***

	Semester 5	
MA3160	Multivariable Calculus	4
MEEM2700	Dynamics	3
EE3160	Signals and Systems	3
	HASS EC/PSY/SS Elective	3
EE3171	Microcontrollers for CPS	4
OR		
EET4141	Microcontroller Interfacing	4
	Total	***17***

	Semester 6	
EE3901	Design Fundamentals	2
MEEM3400	Mech Sys Design & Analysis	3
EE3261 or	Control Systems	3
MEEM3750	Dynamic Systems	4
EE 3280	**Robot Operating Systems**	**3**
	Math/Sci Elective	3
	Total	***14/15***

	Semester 7	
EE/MEEM4901	Design Project 1	2
EET/EE3373	Intro to PLC	3
	RE approved elective	3
EE4235	Sensing and Proc in Robotic App	3
	HASS Comp/Comm.	3
	Total	***14***

	Semester 8	
EE/MEEM4910	EE Design Project 2	2
EE4219&4220	Elec Machinery and Drives & Lab	4
OR		
EE4373	Advanced PLC's	4
OR		
MEEM4750	Robotics & Mechatronics	4
OR		
EE4375	**Autonomous Vehicle Design**	**4**
OR		
EE/MEEM4800	**Actuation and Articulation**	**4**
EE/MEEM4xxx	**Technical elective**	**3**
	HASS elective	3
	HASS HU/FA elective	3

Total	***15***
8 semester total	**123/124**

8. Library and Other Learning Resources

Robotics Engineering is related to the disciplines of electrical engineering, mechanical engineering, and computer science. The JRVP library presently serves these disciplines so additional resources, other than those needed for our current degree offerings, are needed.

9. Description of available/needed equipment

No additional equipment is needed to start this program. The needed instructional laboratories are already in use within the Electrical and Computer Engineering Department, the Mechanical Engineering Department, and the Electrical Engineering Technology program within the College of Computing

Robotics-related equipment in ECE, MEEM and MSE This document also contains an inventory of faculty with robotics engineering expertise in those departments, some of their robotics-focused research, and some of the research work done by these faculty that involves undergraduates. In addition it provides the ECE facilities that will be used in teaching Robotics Engineering related courses.

10. Program Costs (Senate Procedure 108.1.1, Proposal 51-04, Finance for new degree programs)

0 .1 Relation to University's Strategic Plan:

Michigan Tech's strategic plan, Education, states for the Education goal that Michigan Tech will: "Provide a distinctive and rigorous action-based learning experience grounded in science, engineering, technology, business, sustainability, and an understanding of the social and cultural contexts of our contemporary world." The plan goes on to state that this is to be accomplished through three subgoals: Student Learning, Transformative Education, and through Educational Programs. Under Student Learning, the strategic plan states, "Continually assess, revew, and improve programs and develop new offerings in emerging disciplinary and interdisciplinary areas." The Transformative Education subgoal states, "Encourage and support high quality, innovative and effective instruction and experiences to enhance student learning." The Educational Programs subgoal states, "Expand programs in response to social and economic needs and challenges." The BS in Robotics Engineering is a new offering in an emerging interdisciplinary area, that will provide high quality instructional experiences with the aim of being responsive to the economic demand for highly trained engineers who have an explicit expertise in robotics engineering. This offering is fully aligned with the university's strategic plan.

In addition, the BS in Robotics Engineering is aligned with the Tech Forward initiative: Data Revolution and Sensing, which has identified "Robotics" as one of three connections, or "bridges" between the College of Engineering and the College of Computing. Robotics Engineering will operate in a similar manner to Computer Engineering, being administratively housed in the department of ECE, accredited through the Engineering Accreditation Commission of ABET (as is Computer Engineering).

10.2 Impact on University Enrollment:

It is anticipated that approximately 200 students will be enrolled in Robotics Engineering by Fall, 2023 (in four years). An analysis of enrollment data at Worcester Polytechnic Institute (WPI), a similarly sized, technologically focused university provides a useful comparison platform. WPI launched a BS in Robotics Engineering in 2007, and in four years gained 225 students enrolled in Robotics Engineering. Further, WPI's enrollment data showed that the offering did not adversely affect the enrollment in other engineering and computer science programs, which continued to strongly grow, nearly doubling in enrollment between 2007 and 2017. Over ten years, enrollment in WPI's ECE (electrical and computer engineering) program grew by 6.6%, in the computer science program by 175%, in mechanical engineering by 50% and while the college of engineering as a whole grew by 91%. By fall, 2017, ten years after its introduction, there were over 400 students enrolled in Robotics Engineering at WPI. Robotics Engineering will draw students who would not otherwise have come to MTU. Finally, the fall 2018 undergraduate enrollment of students pursuing a BS in Electrical Engineering (EEE) is 360 and of those pursuing a BS in Computer Engineering (ECP) is 289; some of these students pursue dual degrees.

10.3 Impact on Resources Required by Department in Which the Program is housed

This program is proposed without requesting additional resources in the department of ECE.

Faculty lines: The existing faculty and departments at MTU (ECE, MERET, Cognitive Sciences, CNSA, ME-EM, and CS) have the expertise and existing course offerings to initially offer the proposed program without additional resources. With growth, faculty should be added in support of the coursework needed, in support of providing the needed capacity in technical coursework. This will need to be done in a distributed way, see section 10.4.

ECE Faculty and ECE student labs: The first 80 students enrolled in the program can be handled by the existing ECE faculty and ECE laboratories. The ECE department has an overall tenured/tenure track faculty ratio of 10.9 and an overall ratio, all faculty, of 13.1 (2017-18, compendium). This assumes that the ECE faculty is restored to its pre summer-2019 strength.

Program growth is expected and as the program grows, it is reasonable to expect resources to flow toward demand. In order to maintain the desired ratios within the ECE department each additional 40 student increment should be accompanied by 1 FTE faculty and plans should be made to add an additional TA to support the lab sections required. In addition, allocating 0.5 faculty toward supporting departments (MEEM, EET/MERET) for each additional 40 students is additionally warranted.

Advising: Once there are 150 additional students enrolled in the ECE department (considering the EEE + ECP + Robotics Engineering students together), an additional advisor will be needed as per NACADA guidelines. Currently the department has 1.55 advisors for 639 students, which is a deficit of 0.5 advisor per NACADA guidelines at present.

Assessment: The ECE department already has two ABET accredited undergraduate programs, (1) Electrical Engineering and (2) Computer Engineering and has strong familiarity with continuous improvement of academic programs through assessment, and the associated administrative responsibilities. No additional resources are needed to handle the administrative burden associated with assessment; this program will rely on internal efficiencies associated with managing assessment of the other two programs.

10.4 Impact on Resources Required By other Units Within the University.

To keep the university ratio of students to faculty at 12:1, for every 120 students who subscribe to the program and add to the university enrollment, in theory 10 instructional faculty would be warranted, in support of the capacity needed in the courses required for the degree (GenEd, ENG, MA, PH, CH, CS, ECE, ME-EM, Cog Sci, and MERET).

The existing faculty at MTU in ECE, MERET and ME-EM have the expertise and existing course offerings to initially offer the proposed program without additional resources. With the exception of two new ECE courses that will be developed, the curriculum is based on existing coursework at the university. As the program grows, instructional faculty and graduate teaching assistants will be needed in support of the needed courses and labs (particularly in the proposed Computing College so as to augment the MERET faculty in support of the robotics core courses). This will assure the needed capacity in technical coursework required for the degree.

Student labs: Growth of this new program beyond approximately 45 students will require corresponding university investment in technical support, robotics laboratory space and equipment to handle the growth. The existing MERET-robotics instructional space supports an undergraduate EET enrollment of 46 (as of Fall, 2018). The MERET faculty have brought in $1.2M in funding over the past six years in support of the EET curriculum which includes a robotics laboratory and associated equipment. It is an estimate that an approximate doubling of students who take the five EET courses in the curriculum (four mandatory courses, one of which is cross-listed with ECE, and one EET courses that is found optionally in the curriculum) from 46 to 90 can be handled with existing personnel and equipment but that growth beyond 90 students in the robotics and supporting courses offered by EET faculty will require investment in those offerings to further increase capacity.

10.5 Assessment of the ability to obtain the necessary resources assuming requested funds are obtained

There is no anticipated initial issue with resources; no funds are initially requested. This program proposal is seen as a strategy for growing MTU enrollment.

Based on last year's MEEM faculty search information, which revealed many faculty applicants with robotics expertise, there is no reason to anticipate that MTU would not be able to find appropriate instructional faculty in support of the BS in Robotics Engineering program if enrollment warrants.

10.6 Past Proposals

The ECE department has not proposed any new degrees in the past five years. Employers strongly seek our graduates, which have an employment rate of 95% or better.

0 .7 Departmental Budget Contribution

The ECE had $6.40 M general fund expenditures in 2016-17, 5.00M of which was in support of instruction. In 2018-19 27.6 faculty, 6.1 staff (including two advisors) and two UAW staff have been employed.

The ECE department has 649 undergraduates and 162 graduate students enrolled in 2018-19 (compendium data). The ECE department generated 4,497 undergraduate student credit hours (SCH), 1,582 masters SCH and 555 doctoral SCH, totalling 6,634 SCH (2017-18 compendium).

If we estimate that 73% of MTU students are in-state, and 27% are out of state (CoE figures), and use the 2018-19 tuition rates of $15,346 for MI residents and $33,426 for out of state residents, ECE's 649 undergraduates yields $13.1 million in tuition with no discount. If we assume a 30% discount rate on tuition, the ECE department's undergraduate enrollment yielded $9.2M in tuition in 2018-19.

If 100 students enroll in the BS in Robotics Engineering program in Fall, 2019, using the same factors as above, $1.4M is generated.

0 .8 How do the benefits from this program compare to other alternatives that are currently under consideration or development. Will approval and allocation of resources to this program preclude the development of other programs

This proposed BS in Robotics Engineering is differentiated from the proposed BS in Mechatronics in the following ways: (1) The BS in Robotics Engineering would be an Engineering Accreditation Commission, ABET-accredited engineering degree, while the BS in Mechatronics would be accredited by a different ABET commission. (2) A direct result of this is that the curriculum includes an engineering design thread -- the iterative approach taken by engineering disciplines to solve problems; this design thread begins in the first-year experience with the common ENG1101/1102 courses, is built upon in the junior year with EE3901, Design Fundamentals, and culminates in the year-long senior design project. (3) the EAC accredited degree programs carry with them the associated minimum requirement of 30 hours of math and basic science training, and the associated minimum 45 degree hours of training in engineering.

Also, in accordance with the BS in Robotics Engineering program educational objectives, we expect that the early career graduates of this program will either:

(1) be successful in applying their knowledge and skills in robotics engineering in finding creative solutions to engineering problems involving robots or robotic systems, in an industrial or research and development setting, as evidenced by becoming a team/group leader or by earning a first promotion by their employer, OR,

(2) leverage their engineering analysis and design capabilities and develop a skill set for successful technical, professional, and/or entrepreneurial leadership positions, as

evidenced by advanced technical certification, an advanced technical or professional degree, or starting a business.

The approval of the BS in Robotics Engineering does not preclude the development of a BS in Mechatronics or any other degree. Rather, the Robotics Engineering program provides additional revenue to the university by recruiting robotics engineering degree-seeking students through having an additional engineering curriculum directly tied to deep interests developed in their high school years. The associated revenue will help provide associated support to grow Robotics as a whole at Michigan Technological University, with a focus on the intersection of Robotics with engineering. If the EET program were to be sunsetted and the BS in Mechatronics to replace that program, or if the BS in Mechatronics program were to begin to exist in conjunction with the EET program, appropriate course substitutions for any retired EET courses or new courses that would be developed will be made to the BS in Robotics Engineering curriculum.

11. Accreditation Requirements

Michigan Tech is accredited by the Higher Learning Commission (HLC, https://www.mtu.edu/provost/accreditation/hlcommission/). The BS in Robotics Engineering will meet HLC criteria 3 and 4.

It is the intent that this program will be accredited by the Engineering Accreditation Commission (EAC) of ABET under the general program criteria. The curriculum design has been set up to meet all of the criteria and in particular, Criterion 5: Curriculum. Table 5.1 shows that in ABET Criterion 5, that curriculum requirements (5a) and (5b) are met. That is, (5a), 31 credits of Math and Basic Science are required, which exceeds the minimum of 30. And, (5b), 68 hours of engineering content are required, which exceeds the minimum requirement of 45. (5c) There is a broad education component that complements the technical content of the curriculum and is consistent with the program educational objectives, and (5d) there is a culminating major engineering design experience that 1) incorporates appropriate engineering standards and 2) is based on the knowledge and skills acquired in earlier coursework.

The program makes use of the same student services, faculty, and facilities from programs that are presently accredited by ABET. The assessment of the student outcomes will make use of processes that are already in place for the existing programs. As per ABET requirements, an accreditation visit will be sought for the fall after the first student graduates.

12. Space needs

No additional space will be needed until the Robotics Engineering program grows to 45 students; at that point additional space, or the creation of additional sections,will be required for the EET/MERET robotics laboratories as described earlier.

13. Planned Implementation Date

Fall semester of 2020

14. Internal Status of the Proposal

Approved by: College of Engineering
Date: 5 December 2019 at Engineering Council

Approved by: Dean’s Council
Date:

Approved by: University Senate
Date: