PROPOSAL FOR A GRADUATE CERTIFICATE NMECHATRONICS

Proposal 33-19

(Voting Units: Academic)

Submitted by the School of Technology

Task Force Committee:
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1. GENERAL DESCRIPTION AND CHARACTERISTICS OF PROGRAM

This proposal recommends the establishment of a Graduate Certificate in Mechatronics at Michigan Tech.

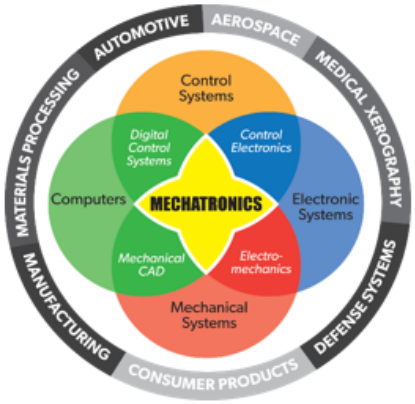


Figure 1: Mix of degrees in the field of Mechatronics

Mechatronics is the synergistic integration of electrical and mechanical engineering, robotics, computational hardware and software in the design of products and processes. Mechatronics is an essential foundation for the expected growth in automation and manufacturing. Figure 1 (source: https://en.wikipedia.org/wiki/Mechatronics) depicts the mix of various science and engineering disciplines that are part of Mechatronics and outlines related job opportunities for degree recipients. There is a demand for graduate education in Mechatronics as the landscape of engineering programs has changed in the past decade, shifting from traditional degrees leading directly to closely aligned positions in industry, to preparing individuals with advanced technical competencies capable of engaging in interdisciplinary research and industry applications. The proposed multidisciplinary degree will fill the need for applied researchers and for entrepreneurs to revitalize the US and global economies in the areas of advanced manufacturing and automation. Graduates will be equipped with multidisciplinary skills in electrical, mechanical, computer, and software engineering. The increased connectivity of smart machinery has resulted in a complete transformation in the technologies used to create new industrial, commercial, and consumer products. The movement towards smart, connected technologies is transforming the manufacturing industry. Emerging technologies will help manufacturers provide advanced automation, improved communication and monitoring, self-diagnosis in real time, and bring data-driven analyses to realize new heights of productivity. The industry-driven curriculum developed for the Master Degree in Mechatronics will be used for the courses associated with a Graduate Certificate in Mechatronics to address the need for a skilled advanced manufacturing workforce and

accelerate the development of a digitally savvy workforce for emerging manufacturing technologies. It will focus on core technical skills, advanced technical design skills, and core technical implementation/instrumentation skills that are used in the design and manufacturing of control systems and devices used in consumer products, aerospace and military applications, and automotive and other advanced manufacturing industries. This Graduate Certificate in Mechatronics is responsive to advice from industrial advisory board members and other industry contacts to meet industry needs and to develop career pathways.

The learning objectives (LOs) for the proposed Graduate Certificate in Mechatronics are listed below.

Learning Objectives

- Demonstrate proficiency in the selected coursework
- Demonstrate professional skills
  - Effective written communication skills
  - Effective oral communication skills
- Practice responsible conduct of the profession

2. RATIONALE AND SURVEY RESULTS

Note: The data collected for Master of Science degree in Mechatronics and its analysis can be directly related to the Graduate Certificate in Mechatronics. Students pursuing undergraduate or graduate studies in different fields will be attracted by the opportunity to receive an additional breath of knowledge and credentials in the field of Mechatronics without necessarily committing to a standalone degree.

Modern industrial processes rely on sensor technology to carry out precise functions, from touchscreen tablets and phones to robotic assembly machines. Advanced manufacturing incorporates complicated electromechanical systems with advanced control systems to increase production quality and throughputs. Mechatronics is the science of receiving, processing, and transmitting sensory data, resulting in advanced control of external devices. Industry has a great demand for engineers with overlapping expertise in the fields of electrical, mechanical, computer, robotic and control engineering. The physical systems currently used in industry are electromechanical with advanced controls. To operate, troubleshoot, and develop new systems, the "ideal" engineer needs knowledge about electrical, mechanical, and computer fields.

As part of the initial assessment of the need for a new type of Master of Science degree in Mechatronics proposed at Michigan Tech, the task force committee surveyed both students at Michigan Tech (in MET, EET, ECE, and ME-EM) and industry representatives.

Graduate certificates in Mechatronics or its close derivatives are more prevalent in the United States as compared to stand alone MS degrees in Mechatronics. For example, the military college of South Carolina is offering 12-credit graduate certificate in Mechatronics Engineering with concentration in control systems. Rochester Institute of Technology's Mechatronics Engineering Certificate program is designed for practicing mechanical and electrical engineers who aspire to become strong contributors to multidisciplinary design and product development teams working in the area of mechatronics. The 9-credit program consists of two online courses in electrical and mechanical engineering, plus an on-campus integrated laboratory applications course in Mechatronics. The University of Utah's Department of

Mechanical Engineering offers a Certificate of Mechatronics open to all matriculated, upper-division College of Engineering students or any student who has a bachelor's degree from a recognized engineering program or an allied science. To obtain the certificate the student must complete 22 credit hours of mechatronics course work, plus a mechatronics project. University of Maryland offers a graduate certificate in Mechatronics for eligible students with a B.S. in either Mechanical or Aerospace Engineering. The certificate focuses on advanced controls, mechatronics system design, and digital electronics. The list of available graduate certificates in Mechatronics can continue being complemented by some purely online programs. Most of the existing certificates are designed around advanced controls, digital electronics and mechatronics systems with little or no emphasis in automation and industrial robotics. The proposed graduate certificate in Mechatronics at Michigan Tech is designed to address this by focusing on industrial robotics, automation and controls.

3. PROJECTED ENROLLMENT

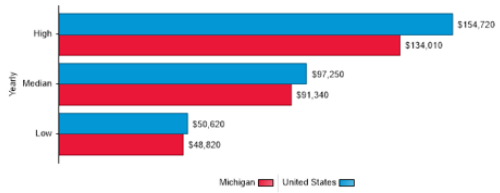
Note: The data collected for the Master of Science Degree in Mechatronics was used to assess the enrolment in the Graduate Certificate with the conclusion that the number of people securing the graduate certificate will be at least the same as the number of students enrolled in the Master of Science Degree in Mechatronics.

Based on initial assessment conducted using the students' survey on the relevance of MS degree in Mechatronics 210 out of 273 students would enroll in the proposed degree. Using an initial conservative rate of 20%, we estimate the Graduate Program to have approximately 40 degree-seeking students over the first three years with an anticipated steady-state enrollment of 40-60 students including international and students from the other universities. Upon program development and availability of the online courses, we expect 80% of the degree-seeking students in the program to be traditional students and the remainder to be industry representatives enrolled through distance learning with intense on-site training. Responsive to the nature of student engagement in the first few years, we will launch a marketing campaign and examine collaborating with Keypath to take the online components to a higher level of professional delivery. The School of Technology already carries the status of a FANUC authorized and certified training center in industrial robotics and offers four industrial certificates of completion: "Roboguide: Robotic Workcell Assembly" (8 hours), "Robot Operations" (16 hours), "Handling Toll Operation and Programming" (32 hours), and "IR-Vision 2D" (32 hour). Enrollments over the past three years have been in the upper twenties; we expect this trend to continue and potentially guide additional industry students into the certificate in Mechatronics. Non-degree seeking students or industry representatives could take courses that can be applied to professional credentials.

In addition, according to the latest U.S. Bureau of Labor Statistics, the number of jobs for Mechatronics Engineers is expected to experience moderate growth, specifically in Michigan and Wisconsin, which needs to be supported by new specialists as shown in the table below. Michigan Tech is strategically located in close proximity to the largest automotive companies that have expressed they are in need of Mechatronics specialists. We expect that the expected growth in jobs for Mechatronics Engineers will

referred from the U.S. Bureau of Labor Statistics.

Summary Report for: 17-2199.05 - Mechatronics Engineers

Median US wages (2017)	$46.75 hourly, $97,250 annual
State wages	
Employment (2016)	133,000 employees
Projected US growth (2016-2026)	Average (5% to 9%)
Projected US job openings (2016-2026)	9,500
Top industries (2016)	Government Manufacturing

have direct and positive impact on the enrollment in the proposed Certificate in Mechatronics. We strongly believe that the unique structure of the proposed graduate program curriculum and the availability of online course delivery will attract both traditional, non-traditional degree seeking, and non-degree seeking students. All the developments in the Master of Science Degree in Mechatronics will a direct positive impact of the students' enrollment in the Graduate Certificate

4. SCHEDULING PLANS

The classes will be taught on the Michigan Tech campus and via a staged rollout approach. Some of the courses that are part of the proposed curriculum already have online versions. The new courses that will be developed as part of this initiative will include online content as well. This type of blended learning course meets the needs of distance and on-campus traditional students. Distance education students from industry will be able to complete theoretical portion of courses online, followed by intense on-site training.

5. CURRICULUM DESIGN

According to Michigan Tech's Senate Policy 411.1, the Mechatronics Graduate Certificate requires a minimum of 15 credits of course work. The Graduate Certificate will be available for graduate students from ECE, EET, MEEM, and MET disciplines as long as they complete required courses in Mechanical, Electrical, and Cybersecurity. The key courses, shown in the Table 1 below, have been selected to fulfill the Graduate Certification requirements. The core courses for the Graduate Certificate and for all disciplines are EET 5144 Real-time Robotics Systems and EET 5373 Advanced PLC. Knowledge of robotic systems and the ability to smartly program robots are necessary skills for Mechatronics graduates. Job descriptions from Tesla, Ford, Fanuc, GM, and many other companies dealing with automation, all call for a specific knowledge of Fanuc robots and Programmable Logic Controllers. This has been a deciding factor for requiring all majors to be enrolled in EET5144 and EET5373. Additional courses have been added to emphasize electrical, mechanical and cybersecurity aspects of the certificate. Supplementary elective courses are available to fulfill the prerequisite requirements for the required courses. The program requirements are listed below. In addition, Table 1 includes recommended courses for students coming from various majors.

Certificate Requirements

Required courses (7)
EET 5144 Real Time Robotics (4)
EET 5373 Advanced PLC (3)

Disciplinary Breadth – Pick one from these two classes (3)
MET 3130 Statics and Dynamics (3)
EET 3373 - Introduction to Programmable Controllers (3)

Dynamic of Robots – Pick one from these two classes (3-4)
MEEM 5705 Introduction to Robotics and Mechatronics (4)
MET 5800 Dynamics and Kinematics of Robotics Platforms (3)

Cyber Security – Pick one from these classes (3)
EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems (3)
SAT 3812 Cybersecurity I (3)

Table 1: Courses for Graduate Certificate in Mechatronics

Disciplines			
Path 1 (suggested for EET major)	Path 2 (suggested for MET major)	Path 3 (suggested for MEEM major)	Path 4 (suggested for EE major)
EET5144 Real-Time Robotics Systems and EET5373 Advanced PLC	EET5144 Real-Time Robotics Systems and EET5373 Advanced PLC	EET5144 Real-Time Robotics Systems and EET5373 Advanced PLC	EET5144 Real-Time Robotics Systems and EET5373 Advanced PLC
MET3130 Statics and Dynamics	EET3373 Introduction to PLC	EET3373 Introduction to PLC	EET3373 Introduction to PLC
MET 5800 Dynamics and Kinematics of Robotics Platforms	MET 5800 Dynamics and Kinematics of Robotics Platforms	MEEM 5705 Introduction to Robotics and Mechatronics	MET 5800 Dynamics and Kinematics of Robotics Platforms
SAT 3812 Cyber Security I	SAT 3812 Cyber Security I	EE 5455/MEEM5300 Cybersecurity of Industrial Control Systems or SAT 3812 Cyber Security I	EE 5455/MEEM5300 Cybersecurity of Industrial Control Systems or SAT 3812 Cyber Security I

Note: Paths 1-4 are suggested pathways for EET, MET, MEEM, and ECE majors based on the available prerequisites. Students from the other majors, perusing the graduate certificate in mechatronics, can select any of four paths as long as they satisfy prerequisite requirements.

6. COURSE DESCRIPTIONS

TABLE 2: SCHEDULE OF COURSE OFFERINGS

Course Title	Pre-requisites	Credits	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET1411 or EET2220 or PH2230 or EE2110 or EE 3010 or MEEM 3750 or MEEM4705	4	Sergeyev	Sergeyev
EET 5373 Advanced PLC	EET3373	3	Hamouz	Hamouz
EET 5311 Advanced Circuits and Controls	EET3131 or EET4253	4	Hazaveh	
MET 5800 Dynamics and Kinematics of Robotics Platforms **(new course)**	MET2130	3	Labyak/Johnson	
MEEM 5705 Introduction to Robotics and Mechatronics	MEEM 4775	4	Sun	
ECE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	MEEM 4775 or EE 3261	3	Goldsmith	Goldsmith
SAT 3812 Cyber Security I	SAT 1200 or CS 1111 or CS 1121 or CS 1131 or CS 1142 or MIS 2100	3	Cai	

Note: The new proposed course MET 5800 has already been included in the 2018-2019 binder process.

Description of the courses for the Graduate Certificate in Mechatronics:

EET 5144 Real Time Robotics

- Covers the components of a robot system, safety, concepts of a work-cell system, geometry, path control, automation sensors, programming techniques, hardware, and software.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3)
- Semesters Offered: On Demand
- Restrictions: Must be enrolled in one of the following Level(s): Graduate
- Pre-Requisite(s): EET 1411 or EET 2220 or PH 2230 or EE 2110 or EE 3010

EET 5373 Advanced PLC

- Using Allen Bradley Control Logix and SLC500 programmable controllers, course covers structured programming, Sequential Function Charts, networking, proportional integral differential control, data acquisition and interfacing. The course requires proposing, executing and defending the graduate level, and related to the course material, project.

- Credits: 3.0
- Lec-Rec-Lab: (0-2-3) Semesters Offered: Spring
- Restrictions: Must be enrolled in one of the following Level(s): Graduate Pre-Requisite(s): EET 3373

MEEM 5705 Introduction to Robotics and Mechatronics

- Cross-discipline system integration of sensors, actuators, and microprocessors to achieve high-level design requirements, including robotic systems. Varieties of sensor and actuation types are introduced, from both a practical and a mathematical perspective. Embedded microprocessor applications are developed using the C programming language. A final project is required including analysis, design, and experimental demonstration. Cannot receive credit for both MEEM4705 and MEEM5705.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3)
- Semesters Offered: Fall, Spring
- Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics
- Pre-Requisite(s): MEEM 3750

MET 5800/4800 Dynamics and Kinematics of Robotics Platforms

- This course covers the dynamics and kinematics of rigid bodies as the foundation for analyzing motion of robots. Robotic kinematics is reviewed by analyzing the motion of the robot. The dynamics is reviewed by analyzing the relation between the joint actuator torques and resulting motion.
- Credits: 3.0
- Lec-Rec-Lab: (0-2-3)
- Semesters Offered: Fall
- Pre-Requisite(s): MET3130

EEE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems

- General introduction to cybersecurity of industrial control systems and critical infrastructures. Topics include NIST and DHS publications, threat analysis, vulnerability analysis, red teaming, intrusion detection systems, industrial networks, industrial malware, and selected case studies.
- Credits: 3.0
- Lec-Rec-Lab: (0-3-0)
- Semesters Offered: On Demand
- Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics
- Pre-Requisite(s): MEEM 4700 or MEEM 4775 or EE 3261 or EET4311

SAT 3812 Cybersecurity I

- The evolution of information security into cybersecurity and its relationship to nations, organizations, society, and individuals. Exposure to multiple cybersecurity technologies,

processes, and procedures; analyzing threats, vulnerabilities and risks present; and developing appropriate strategies to mitigate potential cybersecurity issues. Applied lab to develop cyber security offensive attributes and learn how to prevent and/or mitigate threats.

- Credits: 3.0
- Lec-Rec-Lab: (0-2-2)
- Semesters Offered: Fall, Summer
- Restrictions: Must be enrolled in one of the following Class(es): Junior, Senior
- Pre-Requisite(s): SAT 1200 or CS 1111 or CS 1121 or CS 1131 or CS 1142 or MIS 2100 or EET 2241

EET 3373 - Introduction to Programmable Controllers

- The design of discreet sequential controls using programmable logic controllers (PLCs). Relay logic is used to introduce ladder logic and ladder logic is used to program the PLC. Introduces a structured approach to sequential control design.
- Credits: 3.0
- Lec-Rec-Lab: (0-2-3)
- Semesters Offered: Fall
- Restrictions: Must be enrolled in one of the following Major(s): Electrical Eng. Tech
- Pre-Requisite(s): EET 1411 or (EET 2120 and EET 2141) or EET 2411 or PH 2230 or EE 2110 or EE 3010 or EE 2112

7. LIBRARY AND OTHER LEARNING RESOURCES

Students will have access to all Library resources, Michigan Tech subscription based IEEEXplorer digital database, interlibrary loans, and degree specific subscription-based journals and conference proceedings. Since this Master of Science Degree in Mechatronics builds from foundations in EET, MET, ME-EM, and ECE, additional library and learning resources are expected to be minimal.

8. ADDITIONAL FEES

A university online learning fee of $38/per credit will be required for on-line courses. Laboratory courses are expected to have $50 lab fees and will be adjusted in the future, as usage and infrastructure needs are better understood.

9. FACULTY RESUMES

Key faculty members for this graduate program are listed below:

Graduate Program Director in Mechatronics:
Dr. Sergeyev, https://www.mtu.edu/technology/about/faculty/sergeyev/index.html

Dr. Hamouz, http://www.mtu.edu/technology/about/faculty/
Dr. Hazaveh, http://www.mtu.edu/technology/about/faculty/
Dr. Labyak, http://www.mtu.edu/technology/about/faculty/
Mr. Johnson, http://www.mtu.edu/technology/about/faculty/
Dr. Ye Sun https://www.mtu.edu/mechanical/people/faculty/sun/index.html
Dr. Goldsmith, https://www.mtu.edu/mechanical/people/scholars-instructors/goldsmith/index.html
Dr. Cai, http://www.mtu.edu/technology/about/faculty/cai/

Key staff members for this graduate program are listed below

ECE Academic Advisors: Hassell, P.E. and J.Donahue, https://www.mtu.edu/ece/department/staff/
SoT Academic Advisor: D. Jarvey, https://www.mtu.edu/technology/resources/undergraduate/advising/
MEEM Academic Advisors: T. Stein and R. Towles, https://www.mtu.edu/mechanical/people/staff/

10. DESCRIPTION OF EQUIPMENT

Figure 6: SoT Robotics Lab – Industrial Robotic Workcell

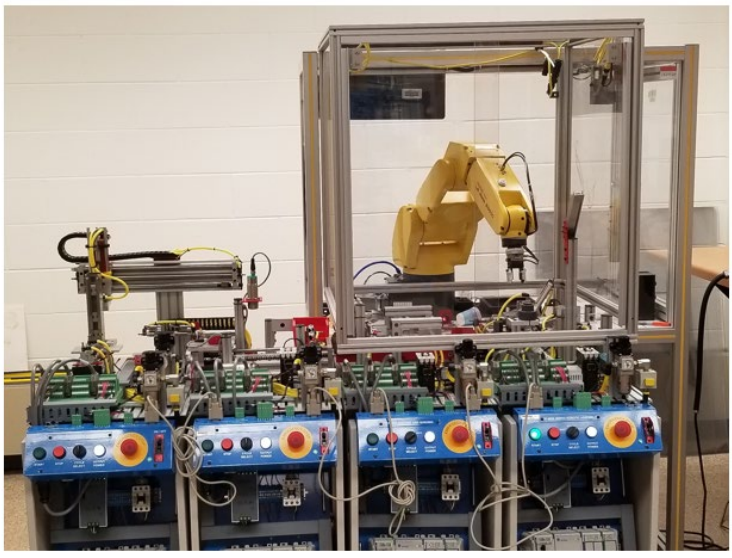


Figure 7: SoT Robotics Lab – Mechatronics assembly line retrofitted with FANUC LR 200iC industrial Robot

The School of Technology, ECE and ME departments are well equipped with various laboratory and research instruments deliver the proposed courses. Some of the equipment and lab resources sharing between EET and ECE as well as ME and MET programs are expected upon mutual agreement. The two courses, Advanced PLC Programming and Real-Time Robotics required for all majors, will be taught in the School of Technology using state- of-the-art laboratory equipment. The SoT robotics lab is equipped with four FANUC LR-Mate 200iC industrial robots retrofitted with advanced FANUC vision system: three of the robots have been assembled as an industrial robotic workcell, shown in Figure 6, and incorporated with the conveyer, various sensors and actuators. The individual control of the robots can be achieved via manual mode utilizing teach pendants. The production mode of all three robots is accomplished via PLC as a master controller and initializing handshaking protocol between the robots. The forth robot is incorporated with four mechatronics stations, Shown in Figure 7. Each mechatronics station is equipped with Allen Bradley ControlLogix PLC enabling individual control for the station's components, as well as handshaking control between all the stations while acting as an assembly line. The SoT PLC lab, shared with ECE department, is equipped with nine the latest Amatrol *990PAB53 Portable PLC Learning Systems*, shown in Figure 8 (a) and one process control system, shown in Figure 8 (b).

This equipment allows teaching modern PLC systems as they are used in the industry today. Students learn both basic and advanced applications using the powerful Allen Bradley Compact Logix 5300 PLC, a

Panel View Plus terminal, and networks throughout the curriculum. The 990PAB53 System comes with a mobile carrying case, workstation mounting panel, master control relay circuit, Allen Bradley Compact Logix 5300 Programmable Controller, RSLinx and RSLogix 5000 software, a Panel View Plus terminal, an Ethernet Switch, I/O Simulator, five application circuits. Learners will study industry relevant skills, including how-to-operate and program PLC systems for a wide range of real-world applications.

Figure 8 (a): SoT and ECE PLC Lab – Amatrol *990PAB53 Portable PLC Learning Systems*

Figure 8 (b): SoT and ECE PLC Lab – *Process Control Systems*

The 990PAB53 Learning System enhances learning by featuring a wide array of real-world applications to allow students to implement their programs and control real systems. In addition to a discrete I/O simulator with discrete switches and indicators, the 990PAB53 includes application circuits and components for thermostatic temperature control, analog temperature control, reversing constant speed motor control, variable speed motor control with feedback, and stepper motor homing and commissioning. These circuits include basic and advanced applications starting with discrete I/O projects and extending to projects involving analog I/O. In addition to all the features mentioned above, the portable system has outstanding capabilities of fault insertion of software and hardware levels and features 35+ electrical faults. The fault insertion capability provides students with unique, real world like opportunity to troubleshoot the industrial equipment in academic settings.

Availability of the state-of-the-art industrial equipment are important to enable the teaching of critical skills that are very relevant to current industry needs. Currently, laboratory equipment associated with teaching introductory and advance concepts of Programmable Logic Controllers is adequate for a class of 50 students with three laboratory sections. Robotics equipment that is used in Real-Time Robotics and Robotic Vision courses can accommodate a class of 36 students with three laboratory sections. Upon the growth of the program enrollment and subject to available profit, additional equipment will be acquired to support larger classes and provide valuable hands-on training with adequate equipment to student's ratio. The Dean of the School of Technology is currently communicating with potential industrial partners, donors, and friends to bolster the equipment availability.

11. PROGRAM COSTS

Since all the courses included in the Graduate Certificate in Mechatronics are part of the Master of Science in Mechatronics, no additional costs beyond those outlined there are anticipated.

Note: Upon the growth in enrollment, the revenue derived from the Graduate Certificate and Master of Science Program in Mechatronics will be used to acquire additional laboratory equipment to adequately

support larger classes. The first priority for the laboratory expansion will be given to Fanuc Industrial Robots, mechatronics and PLC training stations.

12. SPACE

The School of Technology has graduate offices located in EERC #228 (seats approximately 8 graduate students). Additional office space for graduate students will be required. Faculty offices and one research lab has been secured in the EERC.

Lab repurposing involves ongoing coordination between the School of Technology and the Department of Electrical and Computer Engineering. Currently, EERC 418 is undergoing renovations and plans are underway for this to be used for undergraduate EET and ECE students as well as assist with Master's in Mechatronics training. Collaborative research space with ECE as well as ME-EM will be needed for the research projects and will progress via faculty advisor need-based decisions.

13. POLICIES, REGULATIONS AND RULES

Admission Requirements: This Graduate Certificate in Mechatronics is open to excellent candidates who hold or are close to earning a bachelor's degree with sufficient technical and engineering related backgrounds. We anticipate our graduate student population to have undergraduate degrees in technical areas of electrical engineering technology, electrical and computer engineering, mechanical engineering-engineering mechanics, and mechanical engineering technology. Graduate applications will be reviewed the by the Mechatronics Program director in accordance with Graduate School policies.

14. RECOMMENDED TEST SCORES FOR ADMISSION ARE AS FOLLOWS

N/A

15. ACCREDITATION REQUIREMENTS

No Professional Accreditation is required

16. INTERNAL STATUS OF THE PROPOSAL

Approved by: Dean's Council
Date: January 23, 2018

Approved by: Graduate Faculty Council
Date: February 7, 2019

Approved by: University Senate (Curriculum Policy Committee)
Date: (needed by March 2019)

17. PLANNED IMPLEMENTATION DATE

Deployment of the first courses for Graduate Certificate in Mechatronics is expected in fall semester of 2019. This is possible because the proposed degree program relies heavily upon existing courses.