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 Jacqueline E Huntoon

DATE: April 12, 2019

SUBJECT: Senate Proposal 30-19

Attached is Senate proposal 30-19, "Proposal for a Master of Science in Mechatronics," and a memo stating the Senate passed this proposal at their April 10, 2019 meeting. I have reviewed this memo and recommend approving the proposal.

I __x__ concur ________ do not concur

____
Richard Koubek, President

4/12/19
Date

Michigan Tech

University Senate

DATE:	April 11, 2019
TO:	Richard Koubek, President
FROM:	Michael Mullins University Senate President
SUBJECT:	Proposal 30-19
COPIES:	Jacqueline E. Huntoon, Provost & Senior VP for Academic Affairs

At its meeting on April 10, 2019, the University Senate approved Proposal 30-19, "Proposal for a Master of Science in Mechatronics". The Senate looks forward to approval of this proposal by the administration. Please keep me informed about the decision of the administration on this proposal and feel free to contact me if you have any questions.

PROPOSAL FOR A MASTER OF SCIENCE IN MECHATRONICS

Proposal 30-19

(Voting Units: Academic)

Submitted by the School of Technology

Task Force Committee:
Chair: Aleksandr Sergeyev* – Electrical Engineering Technology, School of Technology
Trever Hassel - Electrical and Computer Engineering Department
Kevin Johnson – Mechanical Engineering Technology, School of Technology
Mo Rastgaar – Department of Mechanical Engineering – Engineering Mechanics
Yu Cai – Computer Network and System Administration, School of Technology

***Primary Points of Contact:**
Aleksandr Sergeyev avsergue@mtu.edu and
Adrienne Minerick, Dean, School of Technology, minerick@mtu.edu

1. GENERAL DESCRIPTION AND CHARACTERISTICS OF PROGRAM

This proposal recommends the establishment of a Master of Science in Mechatronics (and Controls System Integration) at Michigan Tech. 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

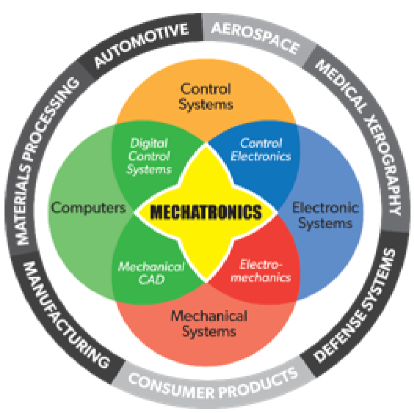


Figure 1: Mix of degrees in the field of Mechatronics

monitoring, self-diagnosis in real time, and bring data-driven analyses to realize new heights of productivity. The industry-driven curriculum developed for the proposed program will 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 degree program is responsive to advice from industrial advisory board members and other industry contacts to meet industry needs and to develop career pathways. *This proposed degree program has the potential to increase enrollments in each of the four feeder BS programs that bridge into the MS in Mechatronics: Electrical Engineering Technology (EET), Electrical and Computer Engineering (ECE), Mechanical Engineering Technology (MET), and Mechanical Engineering - Engineering Mechanics (ME-EM).*

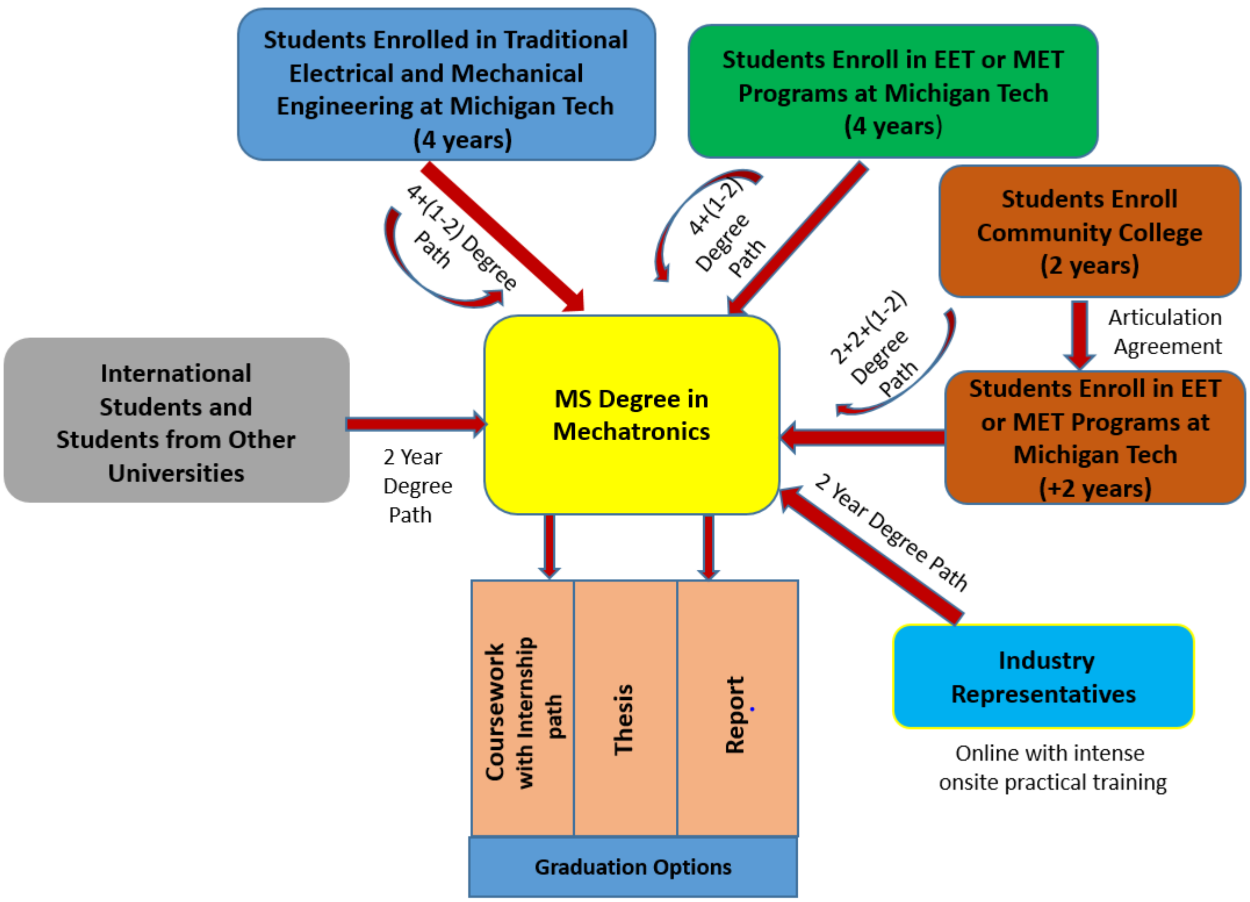


Figure 2: Overview of the proposed model of Master of Science degree in Mechatronics at Michigan Tech

Figure 2 depicts the overview of the proposed MS degree in Mechatronics; each pathway will be discussed beginning at the top and moving clockwise around the figure. The MS degree has been designed to be flexible and accessible to students originating from various disciplines and academic pathways. Students from Michigan Tech pursuing their bachelor's degree will be able to enroll in an accelerated MS degree in Mechatronics and will be available to qualified Michigan Tech undergraduate students who apply in their junior or senior year. Students will be able to apply up to six credits of approved coursework from their BS towards the MS degree in Mechatronics. In addition, up to six (6) credits may be taken under Senior

Rule (in which courses approved for graduate study are taken while students are undergraduates, but the course credits are reserved for the graduate transcript and cannot be used to satisfy undergraduate degree requirements). Depending on the students' preparation (i.e. the number of prerequisites needed for graduate level courses, the number of graduate classes taken during their BS degree, courses transferred using Senior Rule), the graduation time for the students pursuing coursework optioncan vary between 1 and 2 years. For students who elect the research or industry internship option, the graduation time will be minimum of 1.5 years. Students who have earned BS degrees prior to being accepted into the MS Mechatronics program will not be eligible for Senior Rule and thus the Accelerated Master's program but will be able to enroll in the stand-alone 2-year MS in Mechatronics program as shown in Figure 2.

The School of Technology has established and maintains several articulation agreements with regional community colleges. The 2+2+(1-2) degree path will provide these community college students pursuing an associate degree with the opportunity to first obtain a bachelor's degree in electrical or mechanical engineering technology at Michigan Tech and then move into the accelerated MS graduate degree in Mechatronics. These students will be able to follow all pathways enabled above for traditional EET and MET students.

The proposed degree also targets industry representatives who may or may not be able to be full-time students. Discussions with alums suggest there is considerable interest in this Mechatronics degree from those presently working in industry; therefore, online courses will be made available in the second year after program approval and development (potential for partnership with Keypath) for the required masters-level courses. To accommodate the distance, laboratory components will be taught in a week-long format on campus in a condensed fashion at a time that is most convenient for the students. This hybrid (online lectures and in-person hands-on training) approach will not only attract industry representatives but will also provide additional flexibility to the students currently enrolled in the degree.

International students and the students from the other universities will be able to enroll in the MS degree of Mechatronics based upon their earned BS degree, admittance by the graduate school, and approval of the graduate advisor. The approval will be based on comparing the individuals' transcripts with the current requirements for similar courses at Michigan Tech. Given the breadth of possible applications, this will be an iterative optimization with the Graduate School to identify which students to admit into the program. Per graduate school policy, students will be able to take graduate courses at another university and apply to have credits transferred to the MS Mechatronics program. Students will be able to transfer in up to 1/3 of the non-research credits required. The Mechatronics program director will be in charge of approving any allowable credits. Students must earn a 'B' or better in the course they are requesting to transfer.

The proposed MS degree will be very flexible, offering three options to complete graduation requirements: a coursework with internship path; a research option with thesis, and a report. The research option will allow students to work with MET, EET, ECE, and ME-EM faculty members at Michigan Tech on various applied research projects, with the goal of enhancing their knowledge in practical applications. The option most desirable by both students and industry (see survey below), is an internship with industry. Students electing internship option will be able to participate in at least one internship opportunity and acquiring up to at most of 3 credits for a single opportunity with the maximum of up to 6 credits with multiple opportunities. The number of credits awarded for a particular internship opportunity will be decided by the graduate faculty advising to the students. The acquired credits will be counted towards coursework with internship pathway graduation option

The graduate learning objectives (GLOs) for the coursework, thesis, and report pathways of the proposed Master of Science Degree in Mechatronics are listed below. Topic Areas are outlined in Figure 5.

Graduate Learning Objectives

- Demonstrate core proficiency of the hybrid subject matter
- Develop a deeper understanding of the discipline through an appropriate activity.
  - Make a contribution to the discipline. (Thesis option)
  - Expanding student knowledge of the discipline. (Report option)
  - Expanding student knowledge of the field through coursework or coursework with internship
- Demonstrate professional skills
  - Effective written communication skills
  - Effective oral communication skills
- Practice responsible conduct of the profession

2. Rationale and Survey Results

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. A Mechatronics degree prepares graduates with expertise in all of these fields.

As part of the initial assessment of the need for a new type of Master of Science degree in Mechatronics, the task force committee surveyed both students at Michigan Tech (in MET, EET, ECE, and ME-EM) and industry representatives. The student survey targeted currently enrolled engineering students and intended to collect feedback on their perceptions of a new degree: Master of Science in Mechatronics. The survey offered three options to fulfill degree requirements: a) a traditional course-only option; b) a research/project with thesis option; and c) an internship with industry with thesis option. Given the opportunity for the students to extend by 2 years their undergraduate degree to obtain a Master of Science in Mechatronics, the participants were surveyed on two questions: “1) Would you consider this opportunity?; and 2) Which option for the degree completion requirement would you prefer?” Based on 273 responses received in less than a two-week window, the statistical data shown in Figure 3, was compiled.

The industry survey was conducted via an alumni list of recent graduates from the SoT and was open for two weeks. Similar to the student survey, industry representatives were introduced to the proposed initiative and various options for fulfillment of the degree requirements, followed by two questions: “1)

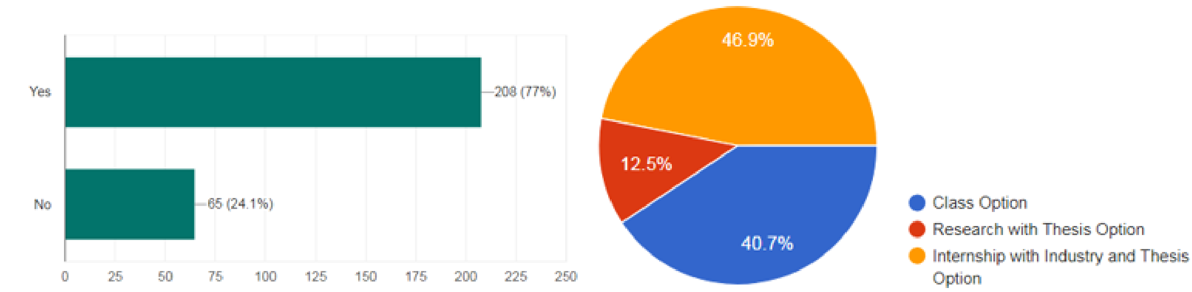


Figure 3: Students' survey on the relevance of Master of Science in Mechatronics at Michigan Tech.

Given the opportunity to hire a graduate with a Mechatronics degree, would this person receive priority over a traditional Electrical or Mechanical Engineering Technology graduate?; and 2) As an employer, which option for the degree completion requirement would you prefer?" Surveyed companies represent a very broad range of industrial sectors: automotive, automation and controls, robotics, additive manufacturing, mechatronics, material handling, energy services, power, steel, computer hardware, industrial machinery, hydraulics, mining, heavy equipment manufacturing, and others. A total of 105 responses were received and the statistical data, shown in Figure 4, was compiled.

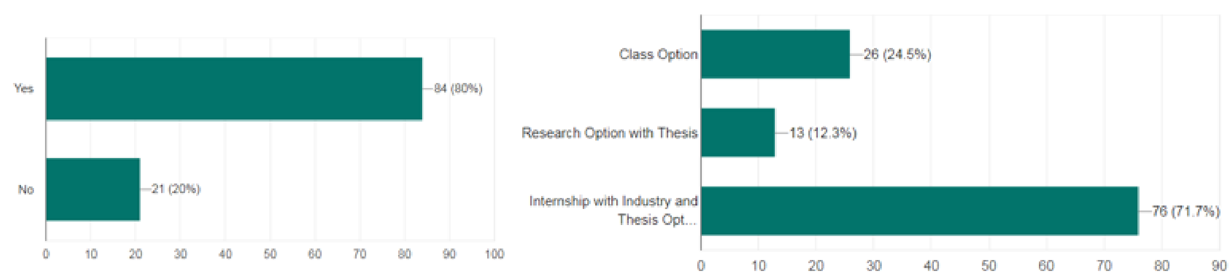


Figure 4: Industry response on the necessity of the Master degree in Mechatronics

Analysis of both data sets clearly indicates that there is a great interest in a Master of Science degree in Mechatronics. Students understand the need for advanced education and are ready to consider a graduate degree, and there is great demand and an immediate need in industry for highly qualified graduates with the proposed degree. 77% of student participants indicated an interest in enrolling in a MS degree in Mechatronics. It is interesting to note that the most preferable degree completion option (at a rate of 47%) is through the internship with industry and thesis option while 41% of students would still prefer to obtain the degree via the coursework option. Based on data collected from a broad spectrum of industry, it is clear that there is a strong (a rate of 80%) preference for graduates with a degree in Mechatronics, as opposed to Electrical or Mechanical engineering technology graduates. Industry prefers a graduate with electrical, mechanical, and computer skills in one package. This type of graduate will enable more productive work in complex industrial solutions and will be well-oriented to communicate with other specialists from various disciplines. Industry responses also show that the internship graduation path is preferred, at a rate of 72%. Industry values graduates who, while still in school, experience real-world, application-based challenges. Graduates with industrial experience and hands-on education are ready to immediately implement their skills and contribute to the company mission.

3. Related Programs

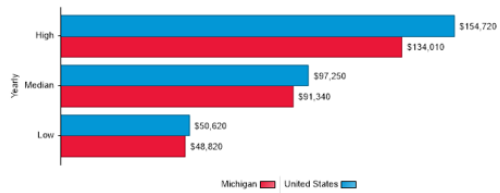
Mechatronics is a very common degree in Europe and Asia; well-known programs are located in Germany, Spain, Czech Republic, France, Russia, Portugal, Canada, Vietnam, China, and Taiwan. However, only a limited number of mechatronics degrees, and especially master's programs, exist in the United States. University of Michigan offers a Master of Science in Robotics with a focus on the research and development of human-robot interactions, bio-inspired compliant systems, robotics, and nano-manipulation. Georgia Tech is also ranked among the best universities in the US for people interested in studying mechanical engineering. Georgia Tech has several laboratories specially created for fields such as precision machining, robotic mechanisms, and advanced intelligent mechatronics. Various courses are available, including robotics and mechatronics. Massachusetts Institute of Technology specializes in applications for robotics, looking for advances such as making humanoid robots, designing mechatronic systems, and implementing robots as tools for real-time computation tasks. The School of Engineering at Stanford University offers a Master of Science degree in Engineering that focuses on the development of solutions using robotic tools. Carnegie Mellon's robotics Master of Science program looks to spread robotics research and solutions across different fields and departments of research and work. The Master's Degree in Robotics offered by Oregon State University remains one of the best and most straightforward options for professional engineers looking to specialize in a program that is versatile and well-reputed. The University of Pennsylvania offers a Master of Science Degree in Robotics and stands out as the one with a high-quality student community, since it attracts multitalented groups of people who have applied robotics to solve different problems. The proposed, interdisciplinary, MS degree in Mechatronics will serve domestic and international students. Currently enrolled students at Michigan Tech in bachelor's degrees electing to advance their degree will be able to enter the accelerated MS degree in Mechatronics. Currently, opportunities for engineering technology students to extend their BS degree are very limited. There are approximately 29 relevant Master of Science in Technology programs worldwide; very few are in the U.S. The Department of Technology at the University of Northern Iowa offers a Master of Science in Technology, but without a specialization in Mechatronics. The College of Technology at Purdue University Northwest offers a Master of Science in Technology with a concentration in Mechatronics Engineering Technology. It is perhaps the closest in nature to the proposed Master of Science degree in Mechatronics at Michigan Tech; however, it lacks flexibility in degree completion requirements.

4. Projected enrollment

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 partnering 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 MS in Mechatronics. Non-degree seeking students or industry representatives could take courses that can be applied to professional credentials. *The details of a proposed graduate certificate are addressed in a separate proposal.*

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

Also, 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 have direct and positive impact on the enrollment in the proposed MS Degree in Mechatronics.

State	Employment 2016	Employment 2026	Percent Change	Projected Annual Job Openings*
Michigan	7,640	8,420	+10%	590
Wisconsin	2,130	2,340	+10%	160

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.

5. Scheduling plans

The classes will be taught on the Michigan Tech campus and via a staged rollout approach, the required courses will be online followed by a majority of the topic area courses (see Figure 5). 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. The courses not currently selected for online delivery are more suitable for on-campus students who intend to write a thesis.

6. CURRICULUM DESIGN

The Mechatronics Graduate Program requires a minimum of 30 credits of coursework and thesis/report for the MS degree. Table 1 outlines options and requirements for the proposed Master of Science degree in Mechatronics.

Option	Minimum Course credits	Research credits	Internship credits (included in course credits)	Minimum Total Credits
Coursework	30			30
Internship path	30		1-6	30
Thesis	20-24	6-10		30
Report	24-28	2-6		30

Table 1: MS Degree Requirements

Figure 5 depicts the curriculum Model for the proposed MS degree in Mechatronics. The model was designed to be flexible enough to accommodate students enrolling from various disciplines: EET, EE, MET ME-EM, and others (subject to adequate preparation). All majors are required to take EET5144 Real Time robotics and EET5373 Advanced Programmable Logic Controllers. Knowledge of robotic systems and the ability to smartly program robots are absolutely 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. The prerequisites are designed to allow students from EET, EE, MET, and ME-EM to be able to enroll in these courses.

In addition, the students need to select at least one course from each of the topics (1-4) containing courses related to key identified knowledge areas for the Mechatronics degree. These topics are Cybersecurity of Industrial Systems, Autonomous Robotic Platforms, Controls of Industrial Systems, and Signal Processing of Electromechanical Systems. Availability of similar-in-nature courses in each Topic area that are offered by different majors will avoid foreseeing conflicts with course prerequisites.

It is expected, and will be required, that students coming from an electrical engineering background will complement their knowledge with mechanical engineering concepts by enrolling in at least one course outside of their discipline, and vice versa for the students with mechanical engineering backgrounds. This will be made possible by supplementing the required courses with various technical elective courses needed to qualify as prerequisites. The degree requirements followed Figure 5 provide more specific information on disciplinary breadth necessities. The specific degree paths, as well as flowchart options, have been developed for all participating majors and available along with the Master of Science Degree plan in Appendix A.

Note: The flowcharts shown in Appendix A are only examples and some of the courses may be substituted with different ones upon the degree evolution.

Required for all Majors

EET 5144 Real Time Robotics
EET 5373 Advanced PLC
EET 5400 Industrial Safety

Add at least 1 course from each of the Topics (1-4)
At least one course from Topics (1-3) must be selected from out discipline

Topic 1: Autonomous Robotic Platforms

EE 5531 Introduction to Robotics
MEEM 5705 Introduction to Robotics and Mechatronics
EET 5147 Industrial Robotic Vision System
MET 5800 Dynamics and Kinematics of Robotic Platforms

Topic 2: Controls of Industrial Systems

EE 4262 Digital and Non-Linear Control
EE/MEEM 5750 Model-Based Embedded Control System Design
MEEM 4775 Analysis and Design of Feedback Control Systems
EET 5311 Advanced Circuits and Controls
MET 5801 Controls of Dynamic Systems
MET 5802 Vibrations of Mechanical Systems

Topic 3: Signal Processing of Electromechanical Systems

EE 4252 Digital Signal Processing and Applications
MEEM 5700 Dynamic Measurements/Signal Analysis
EET 5142/4142 Digital Signal and Image Processing Applications

Topic 4: Cyber Security of Industrial Systems

SAT 3812 Cybersecurity I
EE 4723 Network Security
EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems
EE/MEEM 5315 Cyber Security of Auto Systems

Figure 5 Curriculum Model for MS Degree in Mechatronics

Degree Requirements

Required courses (8)
EET 5144 Real Time Robotics (4)
EET 5373 Advanced PLC (3)
EET 5400 Industrial Safety (1)

Selected Electrical and Mechanical Electives – Pick one from each group (12-15)
Coursework is subject to a limitation of 12 credits at the 3000-4000 level

Disciplinary Breadth Requirement
Choose a minimum of 3 credits with an EE or EET prefix AND
Choose a minimum of 3 credits with an MET or MEEM prefix
from the following 3 groups. Courses that are cross-listed between EE/EET and MET/MEEM cannot be used to satisfy this requirement.

Autonomous Robotic Platforms (3-4)
EE 5531 Introduction to Robotics (3)
MEEM 5705 Introduction to Robotics and Mechatronics (4)
EET 5147 Industrial Robotic Vision System (4)
MET 5800 Dynamics and Kinematics of Robotics Platforms (3)

Controls of Industrial Systems (3-4)
EE 4262 Digital and Non-Linear Control (3)
EE/MEEM 5750 Model-Based Embedded Control System Design (3)
MEEM 4775 Analysis and Design of Feedback Control Systems (4)
EET 5311 Advanced Circuits and Controls (4)
MET 5801 Controls of Dynamic Systems (3)
MET 5802 Vibrations of Mechanical Systems (3)

Signal Processing of Electromechanical Systems (3-4)
EE 4252 Digital Signal Processing and Applications (3)
EET 5142/4142 Digital Signal and Image Processing (4)
MEEM 5700 Dynamic Measurements/Signal Analysis (4)

Selected Electives in Cyber Security of Industrial Processes (3)
EE 4723 Network Security (3)
EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems (3)
MEEM 5315 Cyber Security of Auto Systems (3)
SAT 3812 Cybersecurity I (3)

Internship pathway (0-6)
EET 5995 Mechatronics Internship (Repeatable 1-6)

Electives (0-10)
Remaining courses are subject to advisor approval and the limitation of a maximum of 12 credits at the 3000-4000 level. Example courses are shown below.

Possible Elective Courses by Major
EET 5144/4144 Real Time Robotics
EET 5147/4147 Industrial Robotic Vision System

EET 5373/4373 Advanced PLC
EET 5311/4311 Advanced Circuits and Controls
EET 5142/4142 Digital Signal and Image Processing
EET 3131 – Instrumentation
EET 3141 - Computer Architecture and Design
EET 3373 - Introduction to Programmable Controllers
EET 4141 - Microcontroller Interfacing
EET 4253 - LabVIEW Programming for Data Acquisition
EET 4367 - Wireless Communications

EE 4723 Network Security
EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems
EE 4262 Digital and Non-Linear Control
EE 4272 Computer Networks
EE/MEEM 5750 Model-Based Embedded Control System Design
EE 5531 Introduction to Robotics
EE 4252 Digital Signal Processing and Applications
EE 4253 Real Time Signal Processing
EE4295 Introduction into Propulsion System for HEV
EE 3160 Signal and Systems
EE 3261 Control Systems

MEEM 5310 Cyber Security of Auto Systems I
MEEM 6320 Cyber Security of Auto Systems II
MEEM 4775 Analysis and Design of Feedback Control Systems
MEEM 4707 - Autonomous Systems
MEEM 4295 - Introduction to Propulsion Systems for Hybrid Electric Vehicles
MEEM 3750 - Dynamic Systems
MEEM 5705 Introduction to Robotics and Mechatronics
MEEM 5700 Dynamic Measurements/Signal Analysis

MET 5801/4801 Controls of Dynamic Systems
MET 5800/4800 Dynamics and Kinematics of Robotics Platforms
MET 5802/4802– Vibrations of Mechanical Systems
MET 5378/4378 – Advanced Hydraulics: Electro-hydraulic Components and Systems

SAT 3812 Cybersecurity I
SAT4812 – Cybersecurity II

EE4272/CS4461: Computer Networks
CS46XX/SAT4XXX/EE4XXX: Computer Vision and Applications (new CS proposed course)

Description of the required courses for MS Degree in Mechatronics:

Required for All Majors:

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

EET 5400 Industrial Safety

- Course covers safety training and background on safe operation of pneumatic, electrical and fluid power system. Recitation component includes lab and facility tours to observe properly and improperly installed/operated systems. The course will survey federal regulations and processes to assess safety and usage impacts, understand responsibilities as equipment designers and operators, and provide practice learning to write Standard Operating Procedures. Provides the technical and cultural background necessary to design, operate and manage a safe manufacturing facility.
- Credits: 1.0
- Lec-Rec-Lab: (0-1-0)
- Restrictions: None

Topic 1: Autonomous Robotic Platforms

EE 5531 Introduction to Robotics

- Introduction to autonomous systems and robotics with focus on automated ground vehicles. Project based course using distributed computing to solve problems related to motion planning, perception, and localization. Requires experience with Linux operating systems variants, version control systems, and C++ or Python.
- Credits: 3.0
- Lec-Rec-Lab: (2-0-3)
- Semesters Offered: Spring
- Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

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. A variety 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

EET 5147 Industrial Robotic Vision System

- Procedures for setting up, teaching, testing, and modifying robot vision systems widely used in industrial automation. Introduces advanced Teach Pendant Programming to develop complex scenarios for integrating robots into industrial cells. Final project must demonstrate proficiency in setting up and programming an advanced robotic vision scenario.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3) Semesters Offered: Fall, Summer
- Restrictions: Must be enrolled in one of the following Level(s): Graduate Pre-Requisite(s): EET 4144 or EET 5144

MET 5800 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

<u>Topic 2: Controls of Industrial Systems</u>

EE 4262 Digital and Non-Linear Control

- Introduction to state space analysis and design (state feedback, observers, and observer feedback); digital control system design and analysis (Z-transforms, difference equations, the discrete-time state model, and digital implementation of controllers); introduction to nonlinear systems (equilibrium states, linearization, phase plane analysis, and describing function analysis); and experiments with physical systems.
- Credits: 3.0
- Lec-Rec-Lab: (2-0-2)

- Semesters Offered: Spring
- Pre-Requisite(s): EE 3261

EE/MEEM 5750 Model-Based Embedded Control System Design

- This course introduces embedded control system design using model-based approach. Course topics include model-based embedded control system design, discrete-event control, sensors, actuators, electronic control unit, digital controller design, and communications protocols. Prior knowledge of hybrid electric vehicles is highly recommended.
- Credits: 3.0
- Lec-Rec-Lab: (0-2-2)
- Semesters Offered: Spring
- Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering; 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 4261 or EE 3261

MEEM 4775 Analysis and Design of Feedback Control Systems

- This course covers topics of control systems design. Course includes a review for modeling of dynamical systems, stability, and root locus design. Also covers control systems design in the frequency domain, fundamentals of digital control and nonlinear systems.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-2)
- Semesters Offered: Fall
- Restrictions: Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics
- Pre-Requisite(s): MEEM 3750

EET 5311 Advanced Circuits and Controls

- Graduate-level students are expected to demonstrate ability in modeling/simulation techniques of linear systems. Topics include: Fourier and Laplace transforms, signal comparison techniques and transfer functions. Control techniques addressed will include feedback, cascade, feedforward, multivariable and model-based methods.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3) Semesters Offered: Fall
- Restrictions: Must be enrolled in one of the following Level(s): Graduate Pre-Requisite(s): EET 3131 or EET 4253

MET 5801 Controls of Dynamic Systems

- This course covers the modeling, analysis, and control of dynamic systems. It uses the controlling equations for the control of mechanical and electrical systems. Theory is verified with simulation and lab testing.
- Credits: 3.0
- Lec-Rec-Lab: (0-2-3)
- Semesters Offered: Spring
- Pre-Requisite(s): MET4800

MET 5802 Vibrations of Mechanical Systems

- This course deals with the modeling and analysis of mixed physical systems. Introduction to modeling and oscillatory response analysis for discrete and continuous mechanical and structural systems. Time and frequency domain analysis of linear system vibrations. Vibration of multi-degree-of-freedom systems. Free vibration eigenvalue problem. Un-damped system response and viscously damped systems. Vibration of continuous systems with modes of vibration.
- Credits: 3.0
- Lec-Rec-Lab: (0-2-3)
- Semesters Offered: Fall
- Pre-Requisite(s): MET2130

Topic 3: Signal Processing of Electromechanical Systems

EE 4252 Digital Signal Processing and Applications

- Digital signal processing techniques with emphasis on applications. Includes sampling, the Z-transform, digital filters and discrete Fourier transforms. Emphasizes techniques for design and analysis of digital filters. Special topics may include the FFT, windowing techniques, quantization effects, physical limitations, image processing basics, image enhancement, image restoration and image coding.
- Credits: 3.0
- Lec-Rec-Lab: (3-0-0)
- Semesters Offered: Fall
- Co-Requisite(s): EE 4259
- Pre-Requisite(s): EE 3160

EET 5142/4142 Digital Signal and Image Processing

- Provides students with digital signal and image processing techniques with emphasis on applications. Covers concepts of sampling, digital filters and discrete Fourier transforms, image processing, enhancement, and restoration. The course requires proposing, executing and defending the graduate level, and related to the course material, project.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3) Semesters Offered: Spring
- Restrictions: Must be enrolled in one of the following Level(s): Graduate Pre-Requisite(s): EET 4311 or EET 3367 and EET 4141

MEEM 5700 Dynamic Measurements/Signal Analysis

- Assessment of measurement system requirements: transducers, conditioners, and displays of dynamic measurements. Time-, frequency-, probabilistic-, and correlative-domain approaches to dynamic signal analysis: sampled data, discrete Fourier transforms, digital filtering, estimation errors, system identification, calibration, recording. Introduction to wavelet analysis. All concepts reinforced in laboratory and simulation exercises.
- Credits: 4.0
- Lec-Rec-Lab: (0-3-3)
- Semesters Offered: Fall, Summer

- Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Topic 4: Cyber Security of Industrial Processes

EE 4723 Network Security

- Learn fundamental of cryptography and its application to network security. Understand network security threats, security services, and countermeasures. Acquire background knowledge on well-known network security protocols. Address open research issues in network security.
- Credits: 3.0
- Lec-Rec-Lab: (3-0-0)
- Semesters Offered: Fall, Spring
- Pre-Requisite(s): EE 4272 or CS 4461

EE 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

MEEM 5315 Cyber Security of Auto Systems

- Modern automotive control and communications systems from a cyber-security perspective. Topics include: V2X communications, vehicle attack surfaces and vulnerabilities, in-vehicle networks, threat analysis and vulnerabilities, security mechanisms and architectures, security requirements analysis, hardware security modules, and standards.
- Credits: 3.0
- Lec-Rec-Lab: (0-3-0)
- Semesters Offered: Spring
- Prerequisite: MEEM5300
- Restrictions: Graduate Student in EME, MEEM, EEE, ECP, or CSS

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

Internship Course

EET5995

- Empirical experiences in an approved internship site. Provides practical experience in one or more work settings, assisting the upper level student in making an appropriate career choice. Internships must be approved by the department internship coordinator and work minimum of 150 hours for each credit earned.

- Credits: variable up to 3; Repeatable to a Max of 6
- Semesters Offered: Fall, Spring, Summer
- Restrictions: Permission of department required; Must be enrolled in one of the following Major(s): MS Degree in Mechatronics
- Pre-Requisite(s): None

Industry-Driven Curriculum

As can be seen from the industry survey responses, there is high demand for graduates with an advanced degree in Mechatronics. Technology evolves every day, and industry is a first responder to these changes. This rapid evolution should be frequently reflected in the curriculum by updating course topics to leverage current technologies. Due to the interdisciplinary nature and hands-on approach of the Mechatronics field of study, it is crucially important that we as an educational institution seek feedback from industry. The EET, ECE, MET, ME-EM and Computer Network and System Administration (CNSA) programs at Michigan Tech already have Industrial Advisory Boards (IABs) that provide continuous feedback for the undergraduate curriculum. One of the program goals is to form an IAB for the new Master of Science degree in Mechatronics. The task force committee for the proposed Mechatronics degree has already identified and received commitments from the following leading automotive and automation corporations: Tesla, Ford, General Motors, Fanuc Robotics, and Kaufman Engineered Systems.

Tesla, the leading automotive company in the production of advanced electrical vehicles, has identified an urgent need for mechatronics specialists with a controls background. Tesla has committed to collaborate with Michigan Tech in the advanced mechatronics curriculum development by being part of the new IAB mechatronics committee and advising on emerging changes in technology. Tesla has also expressed an interest in hiring future highly qualified mechatronics graduates prepared by this new MS degree program.

Fanuc Robotics is a leading industrial robot manufacturing company in the U.S and abroad. Fanuc is represented in 5 continents and > 22 countries with more than 100,000 robots installed in the US and 250,000 robots worldwide. The extensive presence of Fanuc robots in industry requires well-trained and certified specialists with a mechatronics background. Fanuc has a long record of commitment of positively impacting undergraduate education at Michigan Tech and has committed to act on the new IAB for the mechatronics degree by advising on curriculum development and modifications in order to stay tuned with current industry needs. Fanuc has a strong record of hiring Michigan Tech students and has expressed an even stronger interest for graduates with an advanced mechatronics degree.

Kaufman Engineered Systems (KES), is the largest in the U.S. integrator of Fanuc robotics solutions. For over 70 years, KES has been a pioneer in complete line automation. The company has a reputation for single-source convenience, responsive service, and unmatched equipment performance. KES has been a long proponent of Michigan Tech. They have demonstrated continuous support for the undergraduate robotic curriculum development in the EET program. KES has expressed a significant demand for mechatronics specialists with skills that are current and relevant to industry needs. KES has committed to serve on the Mechatronics IAB committee to promote the program and advise on curriculum development.

The Ford Motor Company has deep roots of collaboration with Michigan Tech. The relationship started in 1930 when Henry Ford developed Alberta village, where he established one of his sawmills. For many decades, Ford has supported Michigan Tech's mission of providing the best possible educational practices for students. Ford's engagement with Michigan Tech ranges from providing internships and full-time employment opportunities, sponsoring traditional and applied research, sponsoring and advising senior design and Enterprise projects, to supporting summer youth programs for middle and high school students. Ford has expressed a strong interest in the proposed Master's Degree in Mechatronics, since mechatronics specialists are the best-fit engineers for the automotive sector. Not only has Ford committed to be an active member of the Mechatronics IAB, it has also expressed a solid commitment to interviewing and hiring Mechatronics program graduates.

The partnership between General Motors (GM) and Michigan Tech is called "Made for More." Michigan Tech and General Motors share a long-standing partnership dating back to at least 1940, supporting a wide range of activities across campus including scholarships, Senior Design and Enterprise programs, student organizations, sponsored research, recruiting support, youth programs, diversity initiatives, and more. GM is excited about a new program in Mechatronics and an opportunity to have access to the pool of highly qualified graduates. GM has agreed to collaborate with Michigan Tech by serving as an external advisor, as part of the newly formed IAB, and to provide valuable industrial feedback on the Mechatronics curriculum development.

In addition to these committed corporations who will serve on the new IAB for the Master's Degree in Mechatronics, we will also solicit additional feedback from the companies that are already part of our existing IABs for the related undergraduate programs.

7. Course Descriptions

The actual program of study for each student will be developed in consultation with an advisor and will be based on individual educational goals. Table 2 provides an overview of the schedule of course offerings and the associated instructors. Each of the courses, with the exception of Special Topics, are offered annually with some of the courses being offered in each semester and during summer Tracks A and B. The teaching load for participating faculty members is based on two courses per semester, including current undergraduate teaching assignments. Summer courses will be offered for additional compensation and according to Michigan Tech policies.

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 5147 Industrial Robotic Vision Systems and Advanced Teach Pendant Programming	EET4144	4		Sergeyev
EET 5373 Advanced PLC	EET3373	3	Hamouz	Hamouz
EET 5311 Advanced Circuits and Controls	EET3131 or EET4253	4	Hazaveh	
EET 5142 Digital Signal and Image Processing **(new course)**	EET5311 or EET3367 and EET4141	4		TBD
EET5995 **(new course)**	None	Up to 6	Sergeyev	Sergeyev
EET5400 Industrial Safety **(new course)**	None	1	TBD	TBD
MET 5800 Dynamics and Kinematics of Robotics Platforms **(new course)**	MET2130	3	Labyak	
MET 5801 Controls of Dynamic Systems **(new course)**	MET5800/4800	3	Labyak	
MET 5802 Vibrations of Mechanical Systems **(new course)**	MET2130	3	Labyak	
MET5378 Electrohydraulic Components and Systems **(new course)**	MET4377	3	Johnson	
MEEM 4775 Analysis and Design of Feedback Control Systems	MEEM 3750	4	Parker	
MEEM 5705 Introduction to Robotics and Mechatronics	MEEM 4775	4	Sun	
ECE/MEEM 5750 Model-Based Embedded Control System Design	MEEM 4775	3		Chen
MEEM 5700 Dynamic Measurements/Signal Analysis	Enroll in Col. Of Eng.	4		
ECE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	MEEM 4775 or EE 3261	3	Goldsmith	Goldsmith
MEEM 5310 Cyber Security of Auto Systems	Graduate Student in EME, MEEM, EEE, ECP, or CSS	3		Goldsmith

MEEM 4775 Analysis and Design of Feedback Control Systems	MEEM 3750	4	Parker	
ECE 5531 Introduction to Robotics	NA	3		Boss
ECE 4262 Digital and Non-Linear Control	EE 3261	3		Burl
ECE 4252 Digital Signal Processing and Applications	EE 3160 and EE 4259	4	Amabardar	
ECE 4723 Network Security	EE 4272 or CS 4461	3	Cischke	
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 courses EET5142, MET 5800, 5801, 5802, and 5378 have already been included in the 2018-2019 binder process. The new proposed EET 5995 Internship and EET5400 Industrial Safety courses will be included in the 2019-2020 binder process. EET5400 Industrial Safety course can be offered on demand. Number of research credits can be adjusted to account for either Report or Thesis option.

8. Library and Other Learning Resources

Students will have access to all Library resources, Michigan Tech subscription based IEEEXplorer digital data base, 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.

9. 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.

10. 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. Parker, https://www.mtu.edu/mechanical/people/faculty/parker/
Dr. Ye Sun https://www.mtu.edu/mechanical/people/faculty/sun/index.html
Dr. Chen, https://www.mtu.edu/mechanical/people/faculty/chen/
Dr. Coldsmith, https://www.mtu.edu/mechanical/people/scholars-instructors/goldsmith/index.html

Dr. Bos, https://www.mtu.edu/ece/department/faculty/full-time/bos/index.html
Dr. Burl, https://www.mtu.edu/ece/department/faculty/full-time/burl/index.html
Dr. Amabardar, https://www.mtu.edu/ece/department/faculty/full-time/ambardar/
Mr. Cischke, https://www.mtu.edu/ece/department/faculty/full-time/cischke/index.html
Dr. Cai, http://www.mtu.edu/technology/about/faculty/cai/

Key staff members for this graduate program are listed below

Keypath Lead: Dean, SoT: **Dr. Minerick**, https://www.mtu.edu/technology/about/staff/minerick/
MEEM Department Chair: Dr. Predebon,
https://www.mtu.edu/mechanical/people/faculty/predebon/index.html
ECE Department Chair: Dr. Fuhrmann,
https://www.mtu.edu/ece/department/faculty/fulltime/fuhrmann/index.html
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/

11. DESCRIPTION OF EQUIPMENT

Figure 6: SoT Robotics Lab – Industrial Robotic Workcell

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.

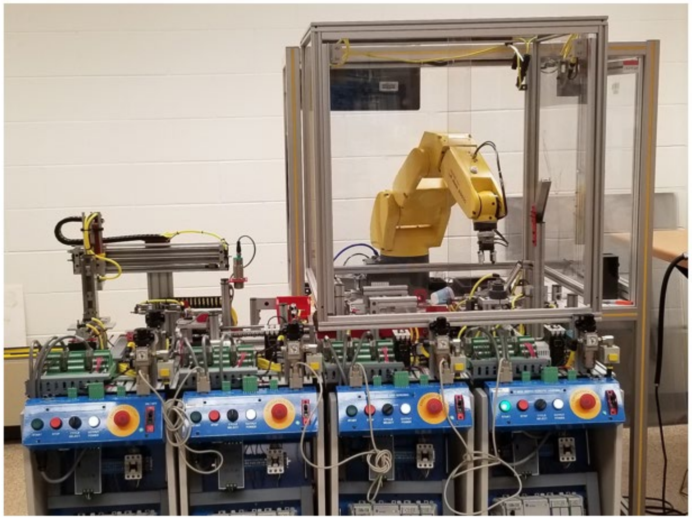


Figure 7: SoT Robotics Lab – Mechatronics assembly line retrofitted with FANUC LR 200iC industrial Robot

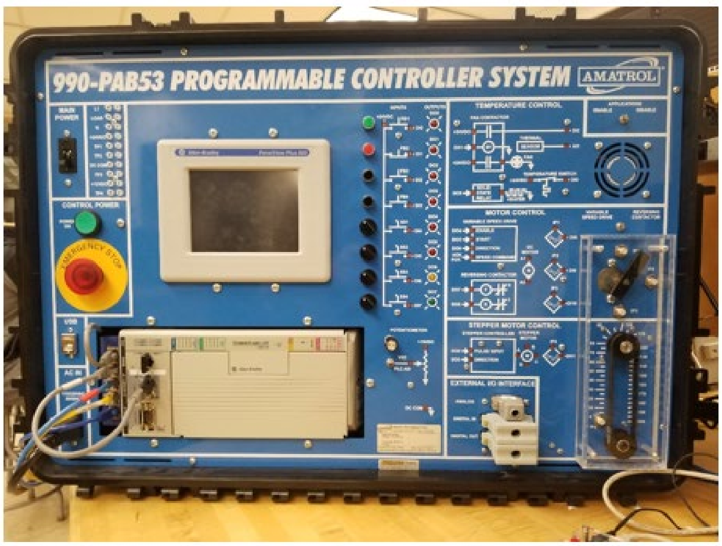


Figure 8 (a): SoT and ECE PLC Lab – Amatrol *990PAB53 Portable PLC Learning Systems*

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

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, RS Linx and RS Logix 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. The 990PAB53 Learning System enhances learning by featuring a wide array of real-world applications to allow students to actually see their programs 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.

12. PROGRAM COSTS

PROGRAM REVENUE	Year 1	Year 2	Year 3	Years 4-n
Enrollment (MS students)	25	30	40	50
Tuition revenue (MS students-15 credits/year at $1,143/credit)	$428,625	$514,350	$685,800	857,250
Tuition revenue (@ 6 certification courses/year/ minimum 3 students in the course with 20% increase every year)	$27,000	$32,400	$38,880	$46,656
Total tuition revenue	**$455,625**	**$546,750**	**$724,680**	**$818,181**
ADDITIONAL PROGRAM EXPENSES				
Program Director (in addition to the faculty salary)	$9,000	$9,360	$9734	$10,124
Professor of Practice /Assistant Professor for EET Yr 1 and MET Yr 2. Subject to enrollment	1	1	1	1
Salary ($75,000, startup $100,000)	$175,000	$253,750	$161,438	$169,510
Graduate Assistantships (3 GTAs or GRAs/year) at $33,141/student increased by 4% per year.	$99,423	$103,400	$107,536	$111,837
Total annual expenses	**$283,423**	**$366,510**	**$278,708**	**$291,471**
REVENUE – EXPENSES	**$172,202**	**$180,240**	**$445,972**	**$526,710**

One-time Startup Costs:

Marketing & Recruiting	$ 10,000

Courses development	$ 48,000
Total One Time Costs:	**$ 58,000**

The anticipated revenue and expenses, based on projected enrollment for the first four years, are presented below. Enrollment is expected to reach steady-state by year four. Non-degree seeking students are individuals who are registered to take courses, possibly to obtain their Robotic certificates, but are not enrolled in the Mechatronics Graduate program.

Note: Upon the growth in enrollment, additional laboratory equipment will be acquired to adequately support larger classes. The first priority for the laboratory expansion will be given to Fanuc Industrial Robots, mechatronics and PLC training stations. The revenue funds will be used for additional laboratory acquisition.

13. 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 also 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.

14. POLICIES, REGULATIONS AND RULES

Admission Requirements: This graduate program is open to excellent candidates who 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 following Graduate School policies.

15. RECOMMENDED TEST SCORES FOR ADMISSION ARE AS FOLLOWS:

Bachelor's degree-seeking students with GPAs above 3.0 will be encouraged into the program.

These scores serve as general guidelines for admission. The Admissions Committee, in making its final decision, will consider the combination of professional knowledge, academic excellence, letters of recommendation, and the Student statements.

16. ACCREDITATION REQUIREMENTS

No Professional Accreditation is required

17. INTERNAL STATUS OF THE PROPOSAL

Approved by: Dean's Council
Date: (needed in Nov 2018)

Approved by: Graduate Faculty Council
Date: (needed by February 2019)

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

18. PLANNED IMPLEMENTATION DATE

Deployment of the first courses is expected in fall semester of 2019. This is possible because the proposed degree program relies heavily upon existing courses. Please refer back to Table 2 on pages 17 and 18 for details.

Appendix A: Master and Major Specific Degree Plans

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC
EET 4311 Advanced Circuits and Controls	EET 5147 Robotic Vision Systems	EET 4311 Advanced Circuits and Controls	EET 5147 Robotic Vision Systems
MET 5800 Dynamics and Kinematics of Robotics Platforms	EET 4142 Digital Signal and Image Processing	MET 5800 Dynamics and Kinematics of Robotics Platforms	EET 4142 Digital Signal and Image Processing
MET 5801 Controls of Dynamic Systems	ECE/MEEM 5750 Model-Based Embedded Control System Design	MET 5801 Controls of Dynamic Systems	EE/MEEM 5750 Model-Based Embedded Control System Design
MET 5802 Vibrations of Mechanical Systems	EE 5455/MEEM 5300 Cybersecurity of Industrial Control	MET 5802 Vibrations of Mechanical Systems	EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems
MET4378 Electrohydraulic Components and Systems	MEEM 5315 Cyber Security of Auto Systems	MET4378 Electrohydraulic Components and Systems	MEEM 5315 Cyber Security of Auto Systems
MEEM 4775 Analysis and Design of Feedback Control Systems	EE 5531 Introduction to Robotics	MEEM 4775 Analysis and Design of Feedback Control Systems	EE 5531 Introduction to Robotics
MEEM 5705 Introduction to Robotics and Mechatronics	EE 4262 Digital and Non-Linear Control	MEEM 5705 Introduction to Robotics and Mechatronics	EE 4262 Digital and Non-Linear Control
EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	Research EET/EE/MET 5990 MEEM 5999	EE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	Research EET/EE/MET 5990 MEEM 5999
MEEM 4775 Analysis and Design of Feedback Control Systems		MEEM 4775 Analysis and Design of Feedback Control Systems	Internship EET 5995
EE 4252 Digital Signal Processing and Applications		EE 4252 Digital Signal Processing and Applications	
EE 4723 Network Security		EE 4723 Network Security	
SAT 3812 Cyber Security I		SAT 3812 Cyber Security I	
		Research EET/EE/MET 5990 MEEM 5999	
		Internship EET 5995	

Master's Degree in Mechatronics cross-disciplinary flowchart

Version 18 (March 6, 2019)

EET Degree Example Flowchart: Coursework Option

Fall	Spring	Fall	Spring
SAT 3812 Cyber Security I	EET 5373 Advanced PLC	EET 5311 Advanced Circuits and Controls	MET 5800 Dynamics and Kinematics of Robotic Platforms
EET 5144 Real-Time Robotics Systems	EET 5142 Digital Signal and Image Proc.	5000/4000 Elective	EET 5147 Robotic Vision Systems
MET 3130 Statics and Dynamics			

EET Degree Example Flowchart: Thesis/Report Options

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	SAT 3812 Cyber Security I	EET 5147 Robotic Vision Systems
MET 3130 Statics and Dynamics	MET 5800 Dynamics and Kinematics of Robotic Platforms	EET 5990 Research Credits	EET 5142 Digital Signal and Image Proc.
EET 5990 Research Credits	EET 5990 Research Credits		EET 5990 Research Credits

EET Degree Example Flowchart: Coursework with Internship Path

Fall	Spring	Fall	Spring
SAT 3812 Cyber Security I	EET 5373 Advanced PLC	Internship EET 5995	EET 5147 Robotic Vision Systems
EET 5144 Real-Time Robotics Systems	MET 5800 Dynamics and Kinematics of Robotic Platforms		EET 5142 Digital Signal and Image Proc.
MET 3130 Statics and Dynamics			

Version 18 (March 6, 2019)

MET Degree Example Flowchart: Coursework Option

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	SAT 3812 Cyber Security I	
EET 5311 Advanced Circuits and Controls	EET 5142 Digital Signal and Image Proc.	MET 5801 Controls of Dynamic Systems	
EET 3373 Elective (Service Course)	MET 5800 Dynamics and Kinematics of Robotic Platforms	MET 5802 Vibrations of Mechanical Systems	
	EET 5147 Robotic Vision Systems	MET4378 Electro-hydraulic Components & Systems	

MET Degree Example Flowchart: Thesis/Report Options

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	SAT 3812 Cyber Security I	
EET 5311 Advanced Circuits and Controls	MET 5800 Dynamics and Kinematics of Robotic Platforms	MET 5801 Controls of Dynamic Systems	
EET 3373 Elective (Service Course)	EET 5142 Digital Signal and Image Processing	EET 5990 Research Credits	
MET 5990 Research Credits	MET 5990 Research Credits		

MET Degree Example Flowchart: Coursework with Internship Path

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	SAT 3812 Cyber Security I	EET 5995
EET 5311 Advanced Circuits and Controls	MET 5800 Dynamics and Kinematics of Robotic Platforms	MET 5801 Controls of Dynamic Systems	
EET 3373 Elective (Service Course)	EET 5142 Digital Signal and Image Processing		

MEEM Degree Example Flowchart: Coursework

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	ECE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	5000 Elective
MEEM 4775 Analysis and Design of Feedback Control Systems	EET 5147 Robotic Vision Systems	4000+ Elective	
MEEM 5705 Introduction to Robotics and Mechatronics	MEEM 5700 Dynamic Measurements/Signal Analysis	5000 Elective	
			EET 3373 Elective (Service Course)

MEEM Degree Example Flowchart: Thesis/Report Options

Fall	Spring	Fall	Spring
MEEM 4775 Analysis and Design of Feedback Control Systems	EET 5373/4373 Advanced PLC	ECE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	MEEM 5700 Dynamic Measurements/Signal Analysis
MEEM 5705 Introduction to Robotics and Mechatronics	EET 5147 Robotic Vision Systems	5000+ Elective	5000 Elective
Research MEEM 5999	Research MEEM 5999	Research MEEM 5999	Research MEEM 5999

MEEM Degree Example Flowchart: Coursework with Internship Path

Fall	Spring	Fall	Spring
EET 5144 Real-Time Robotics Systems	EET 5373 Advanced PLC	ECE 5455/MEEM 5300 Cybersecurity of Industrial Control Systems	EET 5995
MEEM 4775 Analysis and Design of Feedback Control Systems	EET 5147 Robotic Vision Systems		
MEEM 5705 Introduction to Robotics and Mechatronics	MEEM 5700 Dynamic Measurements/Signal Analysis	5000 Elective	

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EE Degree Example Flowchart: Coursework Option

Fall	Spring	Fall	Spring
SAT 3812 Cyber Security I	EET 5373 Advanced PLC	EET 5144 Real-Time Robotics Systems	EET 5147 Robotic Vision Systems
EE 4252 Digital Signal Processing and Applications	ECE 4262 Digital and Non-Linear Control	4000+ Elective	5000 Elective
	MET 5800 Dynamics and Kinematics of Robotic Platforms	5000 Elective	EET 3373 Elective (Service Course)

EE Degree Example Flowchart: Thesis/Report Options

Fall	Spring	Fall	Spring
SAT 3812 Cyber Security I	EET 5373 Advanced PLC	EET 5144 Real-Time Robotics Systems	EET 5147/4147 Robotic Vision Systems
EE 4252 Digital Signal Processing and Applications	ECE 4262 Digital and Non-Linear Control	4000+ Elective	5000 Elective
EE 5590 Research Credits	MET 5800 Dynamics and Kinematics of Robotic Platforms	EE 5590 Research Credits	EE 5590 Research Credits
	EE 5590 Research Credits		

EE Degree Example Flowchart: Coursework with Internship Path

Fall	Spring	Fall	Spring
SAT 3812 Cyber Security I	EET 5373 Advanced PLC	EET 5144 Real-Time Robotics Systems	EET5995
ECE 4252 Digital Signal Processing and Applications	ECE 4262 Digital and Non-Linear Control	5000 Elective	
4000+ Elective	EET 5147 Robotic Vision Systems		
	MET 5800 Dynamics and Kinematics of Robotic Platforms		

Note: EET5400 Industrial Safety course can be offered on demand.

Number of research credits can be adjusted to account for either Report or Thesis option.