Michigan Tech

Office Memo

Office of the Provost and
Senior Vice President for Academic Affairs

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TO: Richard Koubek, President

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

DATE: March 27, 2020

SUBJECT: Senate Proposal 32-20

Attached is Senate proposal 32-20, "Bachelor of Science in Mechatronics," and a memo stating the Senate passed this proposal at their March 25, 2020 meeting. I have reviewed this memo and recommend approving this proposal.

I concur___X___ do not concur_______ with this recommendation.

Richard Koubek, President

03/30/2020
Date

Michigan Tech

University Senate

DATE:	March 26, 2020
TO:	Richard Koubek, President
FROM:	Michael Mullins University Senate President
SUBJECT:	Proposal 32-20
COPIES:	Jacqueline E. Huntoon, Provost & Senior VP for Academic Affairs

At its meeting on March 25, 2020, the University Senate approved Proposal 32-20, "Bachelor of Science in Mechatronics". Feel free to contact me if you have any questions.

The University Senate of Michigan Technological University

Proposal 32-20
(Voting Units: Academic)

"Bachelor of Science in Mechatronics"

Submitted by the College of Computing

Date: 02/12/2020
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Mechatronics Task Force:

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John Irwin, MMET Department, College of Engineering
Todd Arney, CNSA Group, College of Computing

1. General description and characteristics of the program

This proposal recommends the establishment of a Bachelor of Science in Mechatronics at Michigan Technological University. Mechatronics is the synergistic integration of electrical and mechanical engineering and engineering technology, industrial robotics, advanced controls, automation, and computational hardware and software, in the design of products and processes. Such a combination of technical competencies that brings the breadth of knowledge across a wide spectrum of engineering, engineering technology, and computing disciplines is an essential requirement for graduates looking to work at the digital factory of the future, in the paradigm which is becoming known as Industry 4.0. Mechatronics is an essential foundation for the expected growth across a broad spectrum of industry sectors including but not limited to automotive, manufacturing, defense, medical, and aerospace.

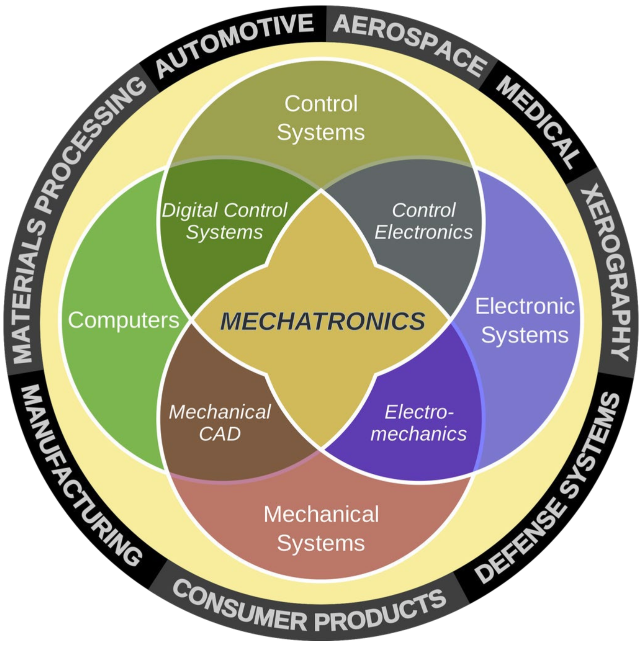


Figure 1. Mechatronics incorporates a mix of four disciplines.

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 in Mechatronics graduates 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 industry applications. The proposed multidisciplinary degree will fill the need for applied engineers and for entrepreneurs to revitalize the U.S. and global economies in the areas of advanced manufacturing and automation. Graduates will be equipped with multidisciplinary skills in electrical, mechanical, robotics, advanced controls, automation, computing, and cybersecurity fields.

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 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 interdisciplinary degree program is built on existing capabilities in Electrical Engineering Technology (EET), Computer Network and System Administration (CNSA), and Computer Science (CS) in the College of Computing, and in Mechanical and Manufacturing Engineering Technology (MMET) in the College of Engineering, and therefore has the potential to increase enrollments in all of these units.*

2. Rationale and survey results

In modern industry, there is a growing need for engineering graduates that are familiar with both electrical and mechanical systems, robotics and automation, controls, and reinforced by the computing, and cybersecurity skills. Examples include hybrid and electric car power trains, combustion engine control, industrial robots, automation and control systems, sensors and actuators; the Internet of Things, and secure communication networks. The proposed undergraduate degree in Mechatronics is designed to offer the student practical knowledge in these and other fields through laboratory-intense coursework.

The U.S. Bureau of Labor Statistics defines the ***Mechatronics*** engineering domain as **development and application** in automation, intelligent systems, smart devices, and industrial control. In contrast, ***Robotics Engineers*** work in the **research and design** domain of robotic applications including autonomous vehicles, and robotic systems. More details, including samples of the possible job titles, are included in Appendix A of this document.

A comparison of labor market data for mechatronics job numbers and related disciplines was conducted. The data, included in Appendix A of this document, was obtained from the U.S. Bureau of Labor Statistics. It shows a clear need for mechatronics graduates at the bachelor's degree level, especially in the State of Michigan.

Figure 2.1 plot summarizes the job market outlook for Mechatronics degree graduates compared to other, closely related, disciplines. It can be seen that:

(a) Mechatronics jobs are amongst the highest paying at $ 46/hour or 95K annually.

(b) In 2018, Mechatronics jobs (at 158,000) outnumber Engineering Technology jobs.

(c) Mechatronics projected job growth (at 5% nationally) is as high as Electrical, Robotics, & Mechanical Engineering. In Michigan, the projected job growth in Mechatronics is 10%.

(d) New Mechatronics jobs (at 11,700) will outnumber Engineering Technology jobs in the next 10 years.

(e) In addition to the clear prospects for Mechatronics graduates nationwide, Figure 2.2 shows that the projected percent job growth for Mechatronics is 10% in the State of Michigan, *i.e.*, double the national growth rate.

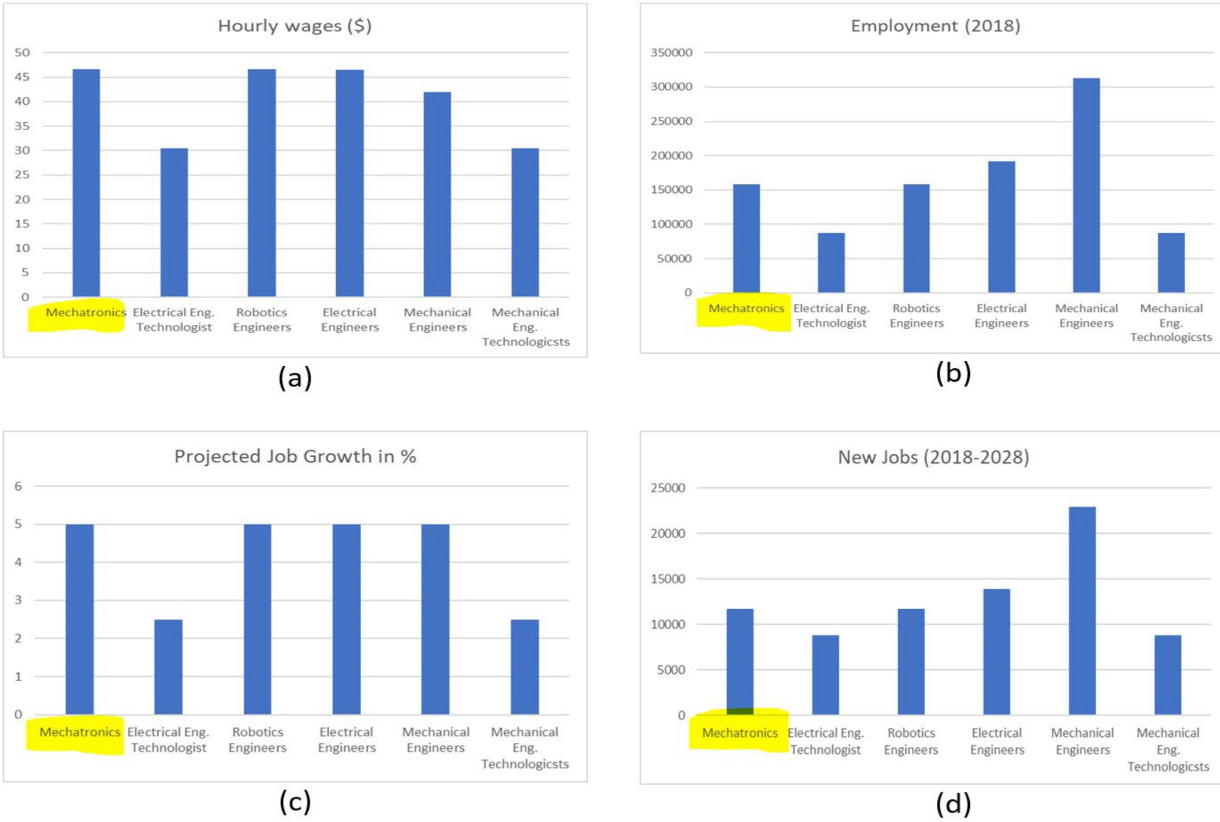


Figure 2.1. Labor market statistics and projection for mechatronics graduates, and other majors. Source: U.S. Bureau of Labor Statistics

Projected Employment for Engineers, All Other in MICHIGAN

View National Data — **View Table** : Vie

National	Employment 2018	Employment 2028	Percent Change	Projected Annual Job Openings*
United States	157,800	163,500	4%	11,700

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

Figure 2.2. Mechatronics job growth projection nationally, and for the State of Michigan.

Source: U.S. Bureau of Labor Statistics

The Mechatronics Task Force has also surveyed industry partners and Michigan Tech alumni, current Michigan Tech students, and students from the other universities and community colleges. We found a resounding interest in a Bachelor of Science degree in Mechatronics and the results of our findings are listed below.

Survey 1: Industry Partners and Michigan Tech Alumni

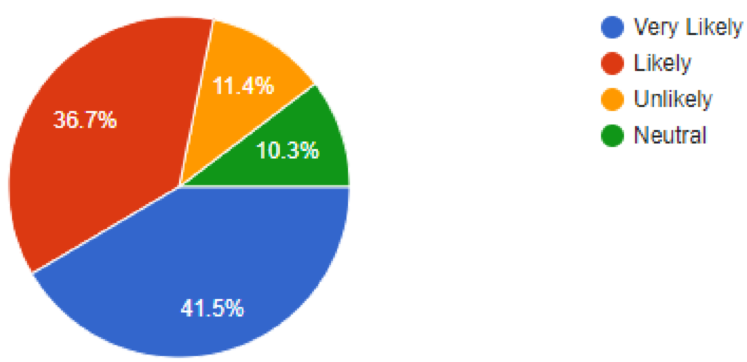
In addition to the information gathered from the U.S. Bureau of Labor Statistics on future needs for mechatronics specialists, the Mechatronics Task Force also surveyed current industry partners and Michigan Tech alumni. The survey consists of three questions:

1. Would your company hire Mechatronics graduates?
2. In the hiring process, would Mechatronics graduates receive priority over traditional electrical or mechanical graduates?
3. Please select the most relevant choice/choices for your company focus area.

The survey received strong attention from industry: 542 responses were collected over four days. Below are the results for all three questions:

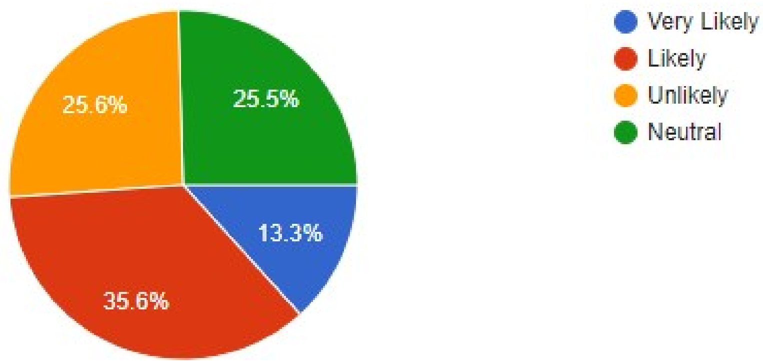
A. Would your company hire a Mechatronics graduate?

542 responses



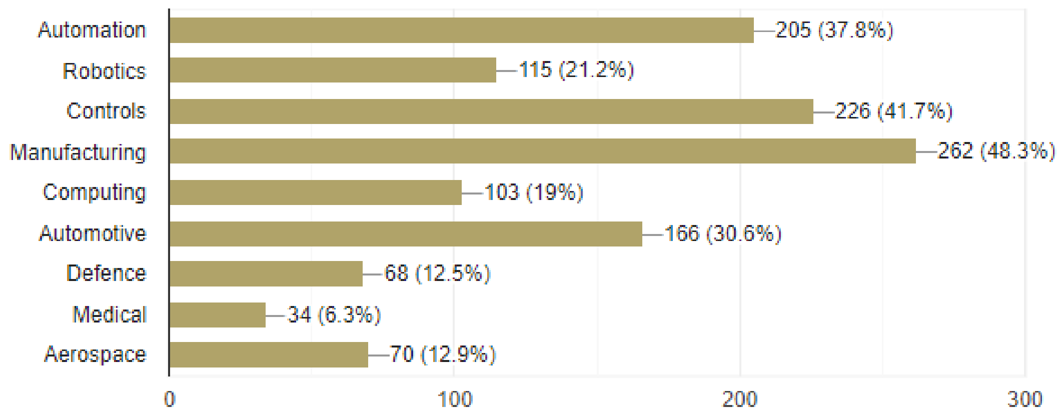
B. In the hiring process, would mechatronics graduates receive a priority over traditional electrical or mechanical graduates?

542 responses



Please select the most relevant choice/choices for your company focus area.

542 responses



As can be seen, the demand for mechatronics specialists is very high - 77% of the companies would hire (very likely and likely responses) mechatronics graduates, and 50% of potential employers would give the preference to mechatronics specialists over traditional electrical or mechanical graduates. The last figure shows that the highest demand in mechatronics specialists is from companies related to manufacturing, automation and robotics, automotive, and controls. Computing expertise in mechatronics specialists is not dominant but carries significant weight. The proposed curriculum addresses the demand of industry key players of the mechatronics job market.

Survey 2: Current Michigan Tech Students

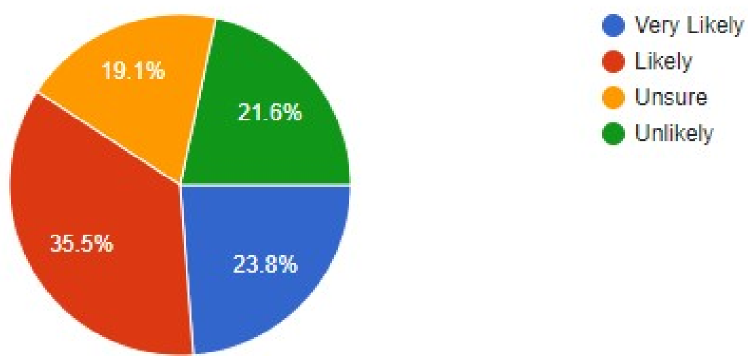
To understand the students' perception of the proposed degree, a survey consisting of two questions was distributed among Michigan Tech students currently enrolled in EET, MET, ECE, MEEM, and CS degrees. In addition to BS degree in Mechatronics at Michigan Tech, it is also intended to offer a Minor/Minors in Mechatronics - FE Minor in Industrial Robotics; Minor in Automation and Controls. To address both initiatives the following questions have been included in the survey:

1. Assuming that you are interested in pursuing a BS degree at Michigan Tech, would you consider Mechatronics degree?
2. If you are currently enrolled in a Michigan Tech BS degree program, would you be interested in pursuing a minor in Mechatronics

The survey also received an excellent response from Michigan Tech students. Over a period of few days 282 responses have been received from Michigan Tech students and results are posted below

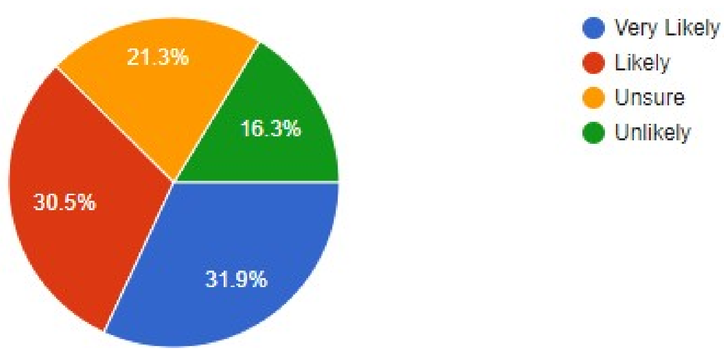
Assuming that you are interested in pursuing a BS degree at Michigan Tech, would you consider Mechatronics?

282 responses



If you are currently enrolled in a Michigan Tech BS degree program, would you be interested in pursuing a minor in Mechatronics?

282 responses



From the survey results, it is obvious that there is a strong interest in BS degree in Mechatronics among Michigan Tech students – 60% of students favored the degree, and another 62% would be very interested for pursuing the minor in Mechatronics. Considering the interdisciplinary nature of Mechatronics degree various minor degrees can be foreseen. The MERET program is ready to launch two minors in: 1) Industrial Robotics and 2) Automation and Controls. Other minor degrees can be developed upon the program evolution. In general, minor degrees provide students with better credentials upon graduation and therefore can promote a better students' retention at Michigan Tech. The goal of the BS degree in Mechatronics and associated minors is to support Michigan Tech's strategic goal of providing better learning opportunities and improving the students' retention.

Survey 3: Students from the other universities and community colleges

In order to understand the perception of the Mechatronics degree by the students outside of Michigan Tech and to get a broader perspective on the proposed degree, the similar survey was distributed to the students from other universities and community colleges. This survey targeted two studies:

1. Likelihood of attracting new students into BS in Mechatronics at Michigan Tech
2. Possibility of attracting transfer students into BS in Mechatronics at Michigan Tech

Two question survey contains the following questions:

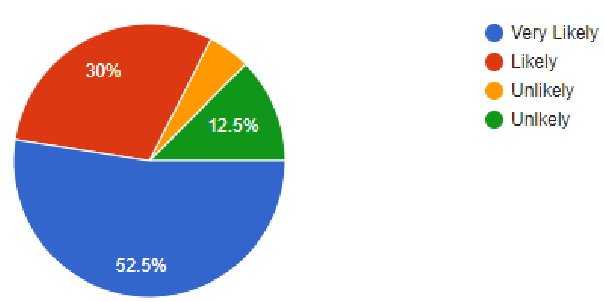
1. Assuming that you are looking for a degree to pursue. Would you consider BS in Mechatronics at Michigan Tech?
2. If you are currently enrolled in a two-year degree program at the community college, would you consider (upon the completion of your 2-year degree) to transfer the required credits to Michigan Tech to continue your degree pursuing the BS in Mechatronics at Michigan Tech?

The response rate for this survey was relatively low which is due to several factors: hard to reach out and have students to participate; thanksgiving break; short collection time of the results (5 days).

The results are provided below:

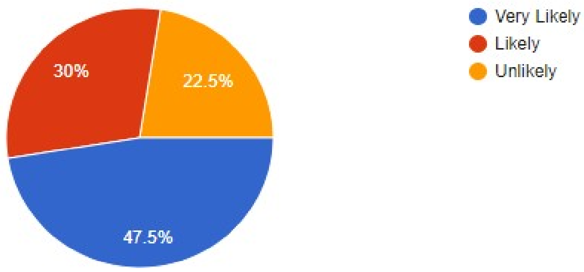
A. Assuming that you are looking for a degree to pursue. Would you consider BS in Mechatronics degree at Michigan Tech?

40 responses



If you are currently enrolled in a two-year degree program at the community college, would you consider (upon the completion of your 2-year degree) to transfer the required credits to Michigan Tech to continue your degree pursuing the BS in Mechatronics at Michigan Tech?

40 responses



Even with the low response rate, it is clear that the interest in Mechatronics degree is high – 81% of outside to Michigan Tech students would highly consider to receive a BS in Mechatronics Degree from Michigan Tech. In addition, 78% of surveyed students would consider to continue their education at Michigan Tech upon receiving their 2-year degree from community colleges. The offering of BS degree in Mechatronics at Michigan Tech will allow for expanding on already existing Michigan Tech articulation agreements with the community colleges nationwide, therefore boosting the overall students' enrollment at Michigan Tech establishing

3. Related programs

Mechatronics is a very common degree name 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 exist in the United States.

3.1. At Michigan Tech

The proposed BS in Mechatronics is an interdisciplinary degree that brings together elements of electrical engineering technology, mechanical engineering technology, computer science, and computer network and system administration, all of which are represented by their own undergraduate programs. The applied and interdisciplinary nature of the Mechatronics degree is the key for the graduates who seek to be highly employable and to "hit the ground running" in their early careers. The curriculum has been designed with industry applications and workforce needs very much in mind.

This proposal is being put forward at the same time as a proposal for a Bachelor of Science in Robotics Engineering, sponsored by the College of Engineering. On the surface the two programs appear to be closely related, with substantial risk of duplication of effort. However, the two new proposed degrees provide different and distinctive educational opportunities for the students at Michigan Tech. The B.S. in Robotics Engineering degree program provides students with the solid knowledge necessary for research and development of autonomous robotic solutions, and builds primarily on material in electrical engineering, mechanical engineering, and computer engineering. In contrast, the B.S. in Mechatronics curriculum places heavy emphasis on industrial robotics, automation and controls, and is geared to students with interests in industrial applications and hands-on experiences. The second differentiator between the two programs is the prominence of computing and cybersecurity in the B.S. in Mechatronics program, as one might expect from a degree program sponsored by the College of Computing. The Mechatronics core also includes 12 credits of Mechanical Engineering Technology coursework which will provide significant background in mechanical aspects of manufacturing processes as well as quality control.

The ECE Department is introducing three new courses as part of the proposed B.S. in Robotics Engineering. These courses would be valuable for students in either program, and they have been added to the list of technical electives for the B.S. in Mechatronics.

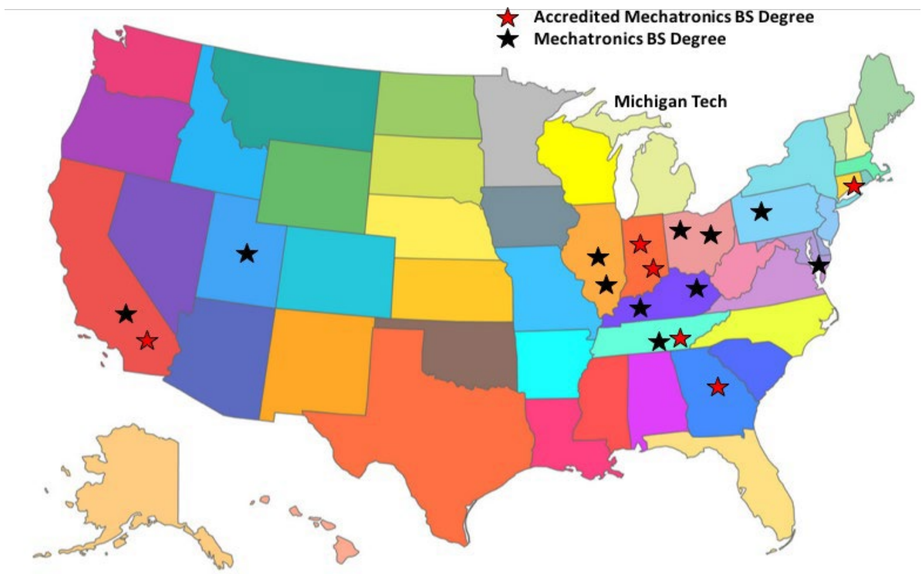
Both the B.S. in Robotics Engineering and the B.S. in Mechatronics will strengthen the educational programs at Michigan Tech, and will provide distinct employment opportunities for the students upon graduation. They could be marketed together, along with other possible degree programs and minors, as Michigan Tech's "Program(s) in Robotics and Mechatronics."

This proposed BS in Mechatronics complements well the existing MS in Mechatronics degree and provides an ideal pathway, among others, for students wishing to pursue the graduate degree in the field.

3.2. In Michigan

The State of Michigan is a stakeholder for automotive industry, which includes major car manufacturers as well as many automotive suppliers. This high concentration of automotive industry calls for mechatronics specialists and the projected percent job growth for mechatronics in 10% in the State of Michigan, *i.e.,* double the national growth rate. In spite of this high demand in Michigan, there are no standalone BS in Mechatronics Degrees in the state (see figure below). There are three Master's programs in Mechatronics (Oakland University, Lawrence Technological University, and Michigan Tech) and a certificate in Mechatronics available in Delta college and Michigan Tech.

The need for individuals educated in Mechatronics is growing in the United States and is estimated to be increased by 4% by 2016 in most states and **by 10% in Michigan**. The map below shows most mechatronic program degrees available in the United States and as can be seen there is a need in Michigan for a strong Mechatronics program. The proposed Mechatronics degree will attract students in the field and will allow Michigan Tech to fill the gap in industry needs.



3.3. In the United States

There are fewer than 15 undergraduate degrees in Mechatronics across the United States, and few of these are ABET accredited. In the table below you can find a list of universities across the United States which offer undergraduate Mechatronics degrees.

Degree Name	University/Location	ABET accredited
BS in Mechatronics Engineering Technology	Purdue University Northwest, Hammond, IN	**Yes**. The first Mechatronics program in the United States to be accredited by TAC-ABET
BS in Mechatronics Engineering	Kennesaw State University, Kennesaw, GA,	Yes
BS in Mechatronics Engineering	Middle Tennessee State University, Murfreesboro, TN, United States	Yes
BS in Mechatronics Engineering Technology	Purdue University, Lafayette, IN, United States	Yes
Robotics & Mechatronics Engineering Technology	Central Connecticut State University, Connecticut	Yes

BS in Mechatronics Engineering Technology	California University of Pennsylvania, California, PA	Undergoing the process
BS in Electronic Systems Engineering Technology with a Concentration in Mechatronics	ECPI University, Virginia Beach, VA	
BS in Mechatronics Engineering	California State University Channel Islands, CA	
BS in Applied Engineering - Mechatronics	Kent State University, Kent, OH	

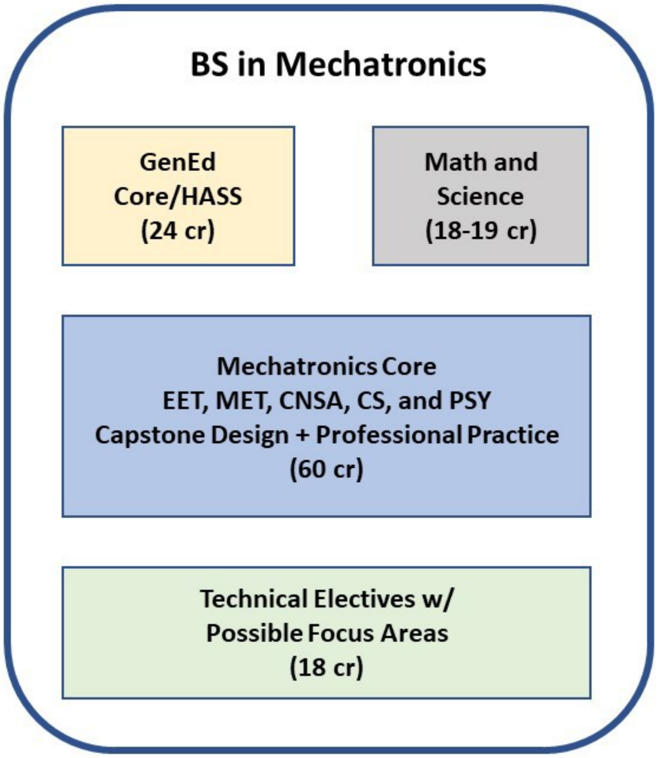
4. Projected enrollment

Based on initial assessment conducted using the students' survey on the relevance of BS degree in Mechatronics, 170 out of 282 students would enroll in the proposed degree. Using an initial conservative rate of 20%, we estimate the program to have approximately 30-35 degree-seeking students in the first few years with an anticipated steady-state enrollment of approximately 150 students within 4 years.

5. Scheduling plans

The classes will be taught on the Michigan Tech Houghton campus. Some courses will be taught in a blended format, providing additional flexibility and breath of knowledge to the students enrolled in the degree.

6. Curriculum design



The figure above depicts the proposed structure of a new BS degree in Mechatronics. The minimum number of credits for the BS in Mechatronics is 120. The degree consists of General Education core and HASS courses (24 credits), math and science (18-19 credits), mechatronics core courses, which cover topics across EET, MET, CNSA, CS, Cybersecurity, and Psychology (60 credits), and technical electives (18 credits). The program culminates in a two-semester mechatronics capstone design experience and a professional practice seminar. There is sufficient flexibility in the technical electives that students can choose different focus areas relevant to mechatronics, such as electrical engineering technology, computer science, robotics, cybersecurity, or mechanical engineering technology, and perhaps even pursue a minor in one of those areas.

General Education Core/HASS Requirements (24 cr)

Core: 12 Credits
HASS: 12 Credits

Math & Science (18-19 cr)

MA 1160 Calculus with Technology 1 (4 cr) **or** MA 1161Calculus Plus with Technology 1 (5 cr)
MA 2160 Calculus with Technology 2 (4 cr.) (MA 1160)
EET2150 Applied Mathematics for Engineering Technology (3 cr) (**new**)
PH 1140 & PH 1141 Applied College Physics I & Lab (4 cr)
One additional science course from GenEd approved list (3 cr)

Mechatronics Core (60 cr)

EET 1120 Circuits I (4 cr)
EET 2120 Circuits II (4 cr)
EET 2233 Electrical Machinery (4 cr)
EET 3131 Instrumentation (3cr) **or** EET 4253 LabVIEW Programming for Data Acquisition (3cr)
EET 3373 Introduction to Programmable Controllers (3 cr)
EET 4141 Microcontroller in Mechatronic Applications (4 cr)
EET 4144 Real-Time Robotic Systems (4 cr)
EET 4311 Controls in Mechatronic Systems (3 cr)

MET 1020 Technology Computer Applications (3 cr)
MET 3130 Statics and Dynamics (3 cr)
MET 4210 Applied Quality Techniques (3 cr)
MET 4377 Applied Fluid Power (3cr)

CS 1090 Introduction to Computing Principles (3 cr) **or** CS 1121 Introduction to Programming 1 (3 cr)
EET 2241 C++and Python Programming (3 cr)
SAT 3812 Cybersecurity I (3 cr)

PSY 3850 Human Factors of Psychology (3 cr)

EET 4999 Professional Practice Seminar (1 cr)
EET4460 Mechatronics Design I (3 cr)
EET4480 Mechatronics Design II (3 cr)

Technical Electives (18 cr)

EET 2141 Digital Electronics & Microprocessor Fundamentals
EET 2220 Devices and Circuits
EET 4147 Industrial Robotic Vision Systems
EET 4373 Advanced Programmable Controllers
EET 4996 Special Topics in Mechatronics
EET 4997 Independent Study in Mechatronics

EET 4998 Undergraduate Research in Mechatronics

EE 2180 Introduction to Robotics
EE 3280 Robot Operating Systems
EE 4532 Sensing and Processing for Robotic Applications

MET 2153 Machine Tool Fundamentals and Applications
MET 2400 Practical Applications in Parametric Modeling
MET 4355 Industrial System Simulation

CS 1122 Introduction to Programming II
CS 1142 Programming at the Hardware Software Interface
CS 2311 Discrete Structures **or** SAT 3830 Discrete Structures for Computing
CS 2321 Data Structures
CS 3311 Formal Models of Computation
CS 3411 Systems Programming
CS 3421 Computer Organization
CS 4312 Introduction to Algorithms
EE 4272/CS 4461 Computer Networks
CS 4471 Computer Security
EE 4723/CS 4723 Network Security
CS 4760 User Interface Design and Implementation
CS 4811 Artificial Intelligence

SAT 1610 Computer and Operating Systems Architecture
SAT 2711 Linux System Administration
SAT 3310 Scripting for Administration, Automation, and Security
SAT 3820 Wireless System Administration and Security
SAT 4310 Advanced Scripting Programming
SAT 4812 Cybersecurity II
SAT 4816 Computer and OS Forensics
MIS 4200 Management of Cybersecurity

PSY 4015 Introduction to Cognitive Task Analysis

Industry-Driven Curriculum

As can be seen from the industry survey responses, there is high demand for graduates with an undergraduate 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, MMET, CNSA, and CS 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

Bachelor of Science degree in Mechatronics. The task force for the proposed Mechatronics degree has already identified and received an agreement from the following leading automotive and automation corporations: Ford, General Motors, Fanuc Robotics, Kaufman Engineered Systems, Donald Engineering, Shunk, Koops, Oilgear, Shape, Clippard Minimatic, and Continental Hydrolics.

7. New course descriptions

To support the new degree in Mechatronics, only one course is proposed to be developed. The MERET, MMET and CNSA programs will also benefit from the development of this course. Upon evolution of the degree additional courses may be developed and included in the curriculum.

EET 2150 Applied Mathematics for Engineering Technology (**New Course**)
3 Credits
Offered in Fall
Course description:

Mathematical theory, mathematical modeling, numerical methods, and algorithms with applications drawn from engineering technology, including electrical, mechanical, mechatronic, and manufacturing engineering technology. Topics covered include complex arithmetic, phasors and complex exponentials, linear algebra, elementary differential equations, and probability and statistics. MATLAB programming is introduced to solve problems encountered in technology with emphasis on modeling of electrical and mechanical systems.

8. Library and other learning resources

Students will have access to all Library resources, Michigan Tech subscription based IEEEXplore digital database, interlibrary loans, and degree specific subscription-based journals and conference proceedings.

Since this BS Degree in Mechatronics builds from foundations in MERET, MMET, CNSA, and CS, 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 $100 lab fees and will be adjusted in the future as usage and infrastructure needs are better understood.

10. Description of equipment

The College of Computing and its CNSA/MERET/HI Division and the CS Department are well equipped with various laboratory and research instruments to deliver the proposed courses. The MERET 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 a conveyer and 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 fourth robot is incorporated with four mechatronics stations, as shown in Figure 7.

Figure 6: SoT Robotics Lab – Industrial Robotic Workcell

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

Each mechatronics station is equipped with an 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 MERET PLC lab, shared with ECE department is equipped with nine of 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

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

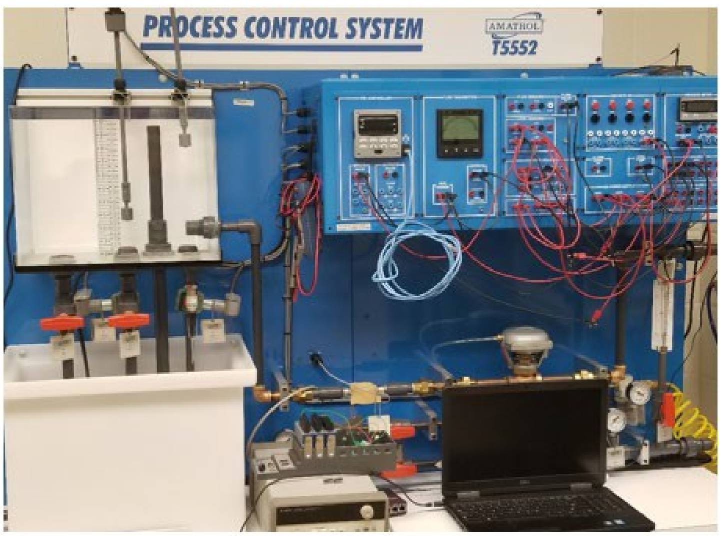
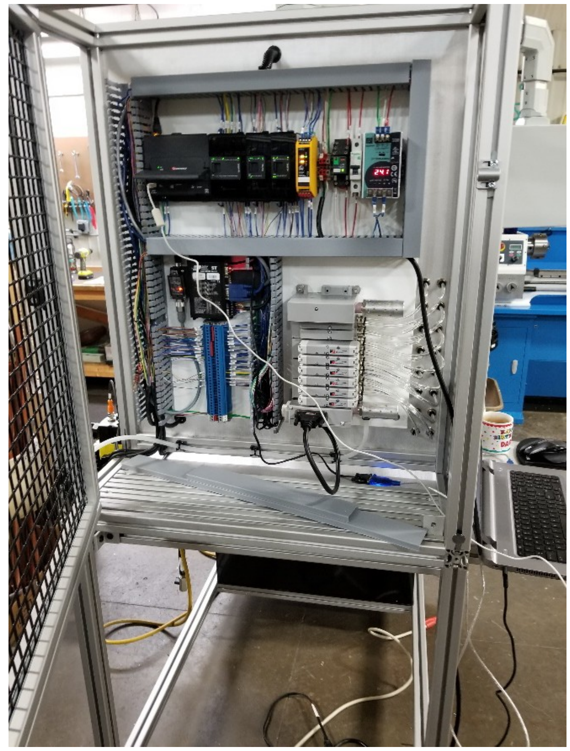


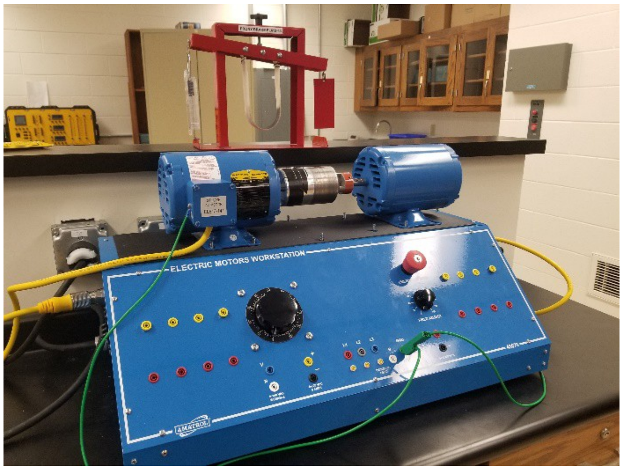
Figure 8 (b): SoT and ECE PLC Lab – *Process Control Systems*

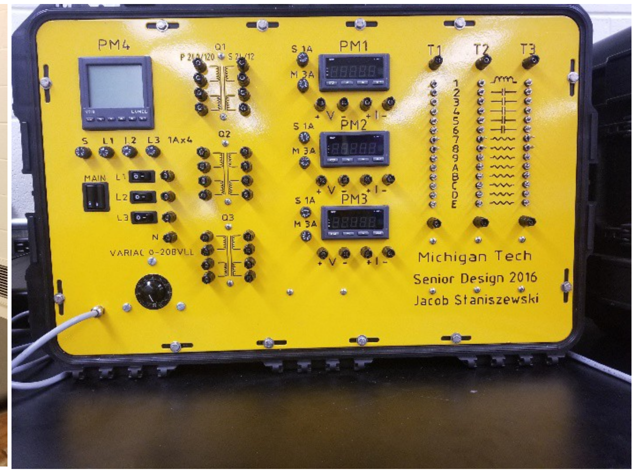
990PAB53 Learning System comes with a mobile carrying case, work-station mounting panel, master control relay circuit, Allen Bradley Compact Logix 5300 Programmable Controller, RS Linx and RS Logix 5000 software, a Panel View Plus terminal, an Ether-net Switch, I/O Simulator, five applica-tion circuits. Learners will study indus-try relevant skills, including how to op-erate and program PLC systems for a wide range of real-world applications. The 990PAB53 Learning System en-hances learning by featuring a wide array of real-world applications to al-low students to actually see their pro-grams control real systems. In addition to a discrete I/O simulator with dis-crete switches and indicators, the 990PAB53 includes application cir-cuits and components for thermostatic temperature control, analog tempera-ture control, reversing constant speed motor control, variable speed motor control with feedback, and stepper motor homing and commissioning. These circuits include basic and ad-vanced applications starting with dis-crete I/O projects and extending to projects involving analog I/O. In addi-tion to all the features mentioned above, the portable system has outstanding capabilities of fault insertion of software and hard-ware 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.

Donald Engineering (DE) company, a strong supporter of Mechatronics initiative at Michigan Tech, donates its time as well a hardware to build state of the art robotic platforms based on the pneumatics solutions and equipped with the PLCs. In addition, the robotics lab will be significantly enhanced by DE donated smart grippers, reconfigurable palletizing end-effectors, and grippers equipped with smart, interchangeable face plates. DE built equipment will significantly broaden the hands-on experience for the students enrolled in PLCs', Industrial robotics, and controls courses of Mechatronics curriculum.


In addition to the developments in automation and controls, the College of Computing Electrical Machinery lab has been recently updated with new Amatrol electrical machine equipment. Seven new stations designated to teaching skills in AC and DC electrical machines and controls have been obtained and installed in the Fall 2019. This update become possible due to the generous support and donation provided by Leidos. In addition to Leidos equipment, MERET faculty have eight portable and low-current, low-voltage stations to teach concepts of single- and 3-phase power, transformers and power factor correction techniques. The electrical machinery course is a core course for Mechatronics and EET degrees and is also a service course for MMET students.





Availability of state-of-the-art industrial equipment is important to enable the teaching of critical skills that are very relevant to current industry needs. Currently, laboratory equipment associated with teaching introductory and advanced 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. Leidos Electrical Machinery and Controls lab can accommodate a class of 50 students with 3 lab 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 College of Computing is currently communicating with potential industrial partners, donors, and friends to bolster the equipment availability.

11. Program costs

- The new course EET 2150 development - $ 10k (Summer 2020)
- Considering acquisition of the new equipment from Donald Engineering, a new set of labs in two PLC and two robotics courses will be required - $10k (Summer 2020).
- Half-time lab technician to support all mechatronics and MERET labs (Note: these labs are also utilized by ECE and MEEM students)

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 funds will be used for additional laboratory acquisition.

12. Space

Adequate space exists in the College of Computing and the College of Engineering to accommodate MERET, MMET, CNSA, and CS faculty. Laboratories located EERC and Rekhi Hall are adequately equipped to provides hands-on practices to the students enrolled in the Mechatronics degree and beyond. Upon program growth, additional space or additional lab sections will be required, especially for Industrial Robotics Lab.

13. Policies, regulations and rules

Admission Requirements:

First time freshmen:
2.75 high school GPA
22 composite ACT or 1110 Composite SAT

Transfer:
2.75 in prior schools

14. Accreditation requirements

Michigan Technological University is accredited as an institution by the Higher Learning Commission (HLC, https://www.mtu.edu/provost/accreditation/hlcommission/). Our accreditation is based in part on compliance with eight Undergraduate Student Learning Goals (USLGs), which apply to all undergraduate degree programs and all undergraduate students at Michigan Tech.

The curriculum for the proposed Bachelor of Science in Mechatronics is consistent with the USLGs, as described below. (Here we have borrowed liberally from the actual text in the publicly available descriptions of the Michigan Tech USLGs, and adapted it to the proposed program.)

(1) Disciplinary Knowledge. Students will demonstrate a *depth* of knowledge in Mechatronics, as well as a *breadth* of knowledge across electrical engineering or electrical engineering technology, mechanical engineering or mechanical engineering technology, industrial control and automation, computer science, information technology, and cybersecurity that (1) enables adaptability and flexibility as the field of Mechatronics and its applications grow and change, and (2) recognizes linkages/complementarity to other areas/disciplines such as human factors, data science, and business.

(2) Knowledge of the Physical and Natural World. Students will demonstrate knowledge of the physical and natural world, through study of science and mathematics, and incorporate their knowledge of mathematical modeling of physical phenomena in the design of industrial control systems and other products and processes.

(3) Global Literacy. Students will demonstrate the ability to understand and analyze issues on multiple scales and from diverse perspectives, acknowledging interconnectivity and complex- ity. As modern manufacturing and Industry 4.0 technologies are adopted worldwide, students will necessarily need to develop a global perspective in order to be successful in their careers.

(4) Critical and Creative Thinking. Students will be able to think critically and creatively, as demonstrated by their broad, adaptable and versatile use of reasoning, logic, and evidence, to access and evaluate information and solve complex problems, both individually and in group settings. Creative thinking skills will be applied to the design, analysis, and testing of mechatronic systems.

(5) Communication. Students will be able to communicate effectively, orally, in writing and in new media, to a wide variety of audiences. This learning is reinforced throughout the curriculum and culminates in the presentations of the capstone design projects in EET4460 and EET4480.

(6) Information Literacy. Students will be able to analyze the need for, strategically access, critically evaluate, and use information effectively, ethically, and legally. This learning is reinforced throughout the curriculum in projects and coursework that go beyond traditional classroom learning toward more specialized efforts.

(7) Technology. Students will demonstrate knowledge of technology and its implications in society, and be able to design and/or use technology for creative activities or innovative solutions to problems. Design and use of technology for creative and innovative solutions to problems is the essence of Mechatronics.

(8) Social Responsibility and Ethical Reasoning. Students will be able to identify and address conflicting ethical values and develop a sense of responsibility for the broad impacts of individual actions and social institutions. They will understand their role as citizens and their responsibility to work with others in promoting quality of life and a sustainable society. These topics are first introduced in the General Education curriculum and reinforced in advanced courses in mechatronics, where the impact of automation and cyber technologies on human society will receive critical attention.

The Bachelor of Science in Mechatronics will be accredited by the Engineering Technology Accreditation Commission (ETAC) of the Accreditation Board for Engineering and Technology (ABET) (http://www.abet.org) under either the program criteria in Electromechanical Engineering Technology, or, what is more likely, the program criteria in Mechatronics Engineering Technology which is currently going through the ABET approval process and is anticipated to be available in approximately one year. The proposed curriculum is designed to meet the latter criteria based on advance information. We note that in programs accredited through the ETAC, if the name of the program contains the word "Engineering" it must be immediately followed by the word "Technology"; however there is no requirement that it contain the phrase "Engineering Technology" at all and we have chosen to omit this phrase. The proposed curriculum and assessment tools draw closely on recent experiences with ABET accreditation for the EET and MET programs. The

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

15. Internal status of the proposal

Approved by: College of Computing
Date:
Approved by: Dean’s Council
Date:
Approved by: University Senate
Date:

16. Planned Implementation Date

Deployment of the first courses is expected in the Fall 2020 semester. This is possible because the proposed degree program relies heavily upon existing courses.

Appendix A: sources for labor market data

17-2199.05 - Mechatronics Engineers

Research, design, develop, or test automation, intelligent systems, smart devices, or industrial systems control.

Sample of reported job titles: Automation Engineer, Automation Specialist, Controls Engineer, Development Engineer, Equipment Engineer, Principal Engineer, Process Engineer, Project Engineer, Senior Design Engineer, Senior Project Engineer

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Wages & Employment Trends

Median wages data collected from **Engineers, All Other**.
Employment data collected from **Engineers, All Other**.
Industry data collected from **Engineers, All Other**.

Median wages (2018)	$46.62 hourly, $96,980 annual
State wages	Local Salary Info
Employment (2018)	158,000 employees
Projected growth (2018-2028)	Average (4% to 6%)
Projected job openings (2018-2028)	11,700
State trends	Employment Trends
Top industries (2018)	Government (24% employed in this sector) Professional, Scientific, and Technical Services (24%) Manufacturing (23%) (see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

17-3029.02 - Electrical Engineering Technologists

Assist electrical engineers in such activities as process control, electrical power distribution, or instrumentation design. May prepare layouts of electrical transmission or distribution systems, supervise the flow of work, estimate project costs, or participate in research studies.

Sample of reported job titles: Design Tech; Electrical Tech/Project Manager; Engineering Tech; Engineering Technologist; Senior Analysis Specialist; Senior Engineering Tech; Senior Process Control Tech; Technologist; Technologist Electronic Design or Technical Director; Technologist, Development

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Wages & Employment Trends

Median wages data collected from **Engineering Technicians, Except Drafters, All Other**.
Employment data collected from **Engineering Technicians, Except Drafters, All Other**.
Industry data collected from **Engineering Technicians, Except Drafters, All Other**.

Median wages (2018)	$30.38 hourly, $63,200 annual
State wages	Local Salary Info
Employment (2018)	87,000 employees
Projected growth (2018-2028)	Slower than average (2% to 3%)
Projected job openings (2018-2028)	8,800
State trends	Employment Trends
Top industries (2018)	Manufacturing (29% employed in this sector) Professional, Scientific, and Technical Services (27%) Government (24%) (see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

17-2199.08 - Robotics Engineers

Research, design, develop, or test robotic applications.

Sample of reported job titles: Automation Engineer, Automation Engineering Manager, Autonomous Vehicle Design Engineer, Design Engineer, Engineering Manager, Engineering Vice President, Factory Automations Engineer, Research Engineer, Robotic Systems Engineer, Robotics and Systems Lead

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Wages & Employment Trends

Median wages data collected from **Engineers, All Other**.
Employment data collected from **Engineers, All Other**.
Industry data collected from **Engineers, All Other**.

Median wages (2018) $46.62 hourly, $96,980 annual

State wages Local Salary Info

Employment (2018) 158,000 employees

Projected growth (2018-2028) Average (4% to 6%)

Projected job openings (2018-2028) 11,700

State trends Employment Trends

Top industries (2018) Government (24% employed in this sector)
Professional, Scientific, and Technical Services (24%)
Manufacturing (23%)
(see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

17-2071.00 - Electrical Engineers

Research, design, develop, test, or supervise the manufacturing and installation of electrical equipment, components, or systems for commercial, industrial, military, or scientific use.

Sample of reported job titles: Circuits Engineer, Design Engineer, Electrical Controls Engineer, Electrical Design Engineer, Electrical Engineer, Electrical Project Engineer, Instrumentation and Electrical Reliability Engineer (I&E Reliability Engineer), Power Systems Engineer, Project Engineer, Test Engineer

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Wages & Employment Trends

Median wages (2018) $46.46 hourly, $96,640 annual

State wages Local Salary Info

Employment (2018) 192,000 employees

Projected growth (2018-2028) Average (4% to 6%)

Projected job openings (2018-2028) 13,900

State trends Employment Trends

Top industries (2018) Manufacturing (34% employed in this sector)
Professional, Scientific, and Technical Services (33%)
Utilities (10%)
(see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

17-2141.00 - Mechanical Engineers

Perform engineering duties in planning and designing tools, engines, machines, and other mechanically functioning equipment. Oversee installation, operation, maintenance, and repair of equipment such as centralized heat, gas, water, and steam systems.

Sample of reported job titles: Application Engineer, Design Engineer, Design Maintenance Engineer, Equipment Engineer, Mechanical Design Engineer, Mechanical Engineer, Process Engineer, Product Engineer, Project Engineer, Test Engineer

Also see: Fuel Cell Engineers, Automotive Engineers

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Wages & Employment Trends

Median wages (2018)	$42.00 hourly, $87,370 annual
State wages	Local Salary Info
Employment (2018)	313,000 employees
Projected growth (2018-2028)	Average (4% to 6%)
Projected job openings (2018-2028)	22,900
State trends	Employment Trends
Top industries (2018)	Manufacturing (49% employed in this sector) Professional, Scientific, and Technical Services (28%) (see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

17-3029.07 - Mechanical Engineering Technologists

Assist mechanical engineers in such activities as generation, transmission, or use of mechanical or fluid energy. Prepare layouts of machinery or equipment o plan the flow of work. May conduct statistical studies or analyze production costs.

Sample of reported job titles: CAD Designer (Computer Aided Design Designer), Engineer Technical Staff, Engineering Tech, Engineering Technologist, Mechanical Designer, Mechanical Designer/Wind-Chill Administrator, Senior Designer, Senior Process Analyst, Technical Staff Engineer, Tooling Engineerinc Tech

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Wages & Employment Trends

Median wages data collected from **Engineering Technicians, Except Drafters, All Other**.
Employment data collected from **Engineering Technicians, Except Drafters, All Other**.
Industry data collected from **Engineering Technicians, Except Drafters, All Other**.

Median wages (2018)	$30.38 hourly, $63,200 annual
State wages	Local Salary Info
Employment (2018)	87,000 employees
Projected growth (2018-2028)	Slower than average (2% to 3%)
Projected job openings (2018-2028)	8,800
State trends	Employment Trends
Top industries (2018)	Manufacturing (29% employed in this sector) Professional, Scientific, and Technical Services (27%) Government (24%) (see all industries)

Source: Bureau of Labor Statistics 2018 wage data and 2018-2028 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2018-2028). "Projected job openings" represent openings due to growth and replacement.

Appendix B: BS in Mechatronics, Sample 8-Semester Schedule

Semester 1 Fall	Semester 2 Spring	Semester 3 Fall	Semester 4 Spring	Semester 5 Fall	Semester 6 Spring	Semester 7 Fall	Semester 8 Spring
UN 1015 Composition (3) [fl,sp,su]	**UN 1025** Global Issues/ Modern Language (3)	Social Responsibility & Ethical Reasoning (3)	Humanities and Fine Arts (3)	Communication/ Composition (3)	HASS Elective (3)	**EET 4460** Mechatronics Design I (3) [fl,sp]	Social Sciences (3)
Critical and Creative Thinking (3)	**PH 1140 & PH 1141** College Physics 1 + Lab (4) [sp]	**EET 2150** Applied Math for Engineering Technology (3) [fl,su]	Non-Physics GenEd Science Course (3)	**EET 2233** Electrical Machinery (4) [fl,su]	**EET 3131 or EET 4253** Instrumentation (3) [sp]	**EET 4141** Microcontrollers in Mechatronics Applications (4) [fl]	**EET 4480** Mechatronics Design II (3) [fl,sp]
MA 1160 (4) or **MA 1161** (5) Calculus w/ Technology [fl,sp,su]	**MA 2160** Calculus w/ Technology II (4) [fl,sp,su]	**CS 1090** Intro to Computing Principles or **CS 1121** Intro to Programming (3) [fl,sp,su]	**EET 2241** C++ and Python Programming (3) [sp,su]	**EET 4144** Real-Time Robotics Systems (4) [fl,su]	**PSY 3850** Human Factors of Psychology (3) [fl]	**EET 4311** Controls in Mechatronic Systems (3) [fl]	**EET 4999** Professional Practice Seminar (1) [fl,sp]
MET 1020 Technology Computer Applications (3) [fl,sp]	**EET 1120** Circuits I (4) [sp]	**EET 2120** Circuits II (4) [fl]	Technical Elective (3)	**SAT 3812** Cybersecurity 1 (3) [fl]	Technical Elective (3)	**MET 4210** Applied Quality Techniques (3) [fl]	**MET 4377** Applied Fluid Power (3) [sp]
		MET 3130 Statics and Dynamics (3) [fl]	Technical Elective (3)	**EET 3373** Intro Programmable Controllers (3) [fl,su]	Technical Elective (3)	Technical Elective (3)	Technical Elective (3)
Co-Curr (0.5)	Co-Curr (0.5)		Co-Curr (0.5)		Co-Curr (0.5)	Co-Curr (0.5)	Co-Curr (0.5)

GenEd Core and HASS | Math and Science | Mechatronics Core | Technical Electives