The University Senate of Michigan Technological University

Proposal 32-20
(Voting Units: Academic)

"Bachelor of Science in Mechatronics"

Submitted by the College of Computing

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Contact: Aleksandr Sergeyev, CNSA/MERET/HI Division, College of Computing
avsergue@mtu.edu
Daniel R. Fuhrmann, CNSA/MERET/HI Division, College of Computing
fuhrmann@mtu.edu
Adrienne Minerick, Dean, College of Computing
minerick@mtu.edu

Mechatronics Task Force:

Aleksandr Sergeyev, MERET Group, CMH Division, College of Computing
Paniz Khanmohammadi Hazaveh, MERET Group, CMH Division, College of Computing
Nathir Rawashdeh, MERET Group, CMH Division, College of Computing
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.
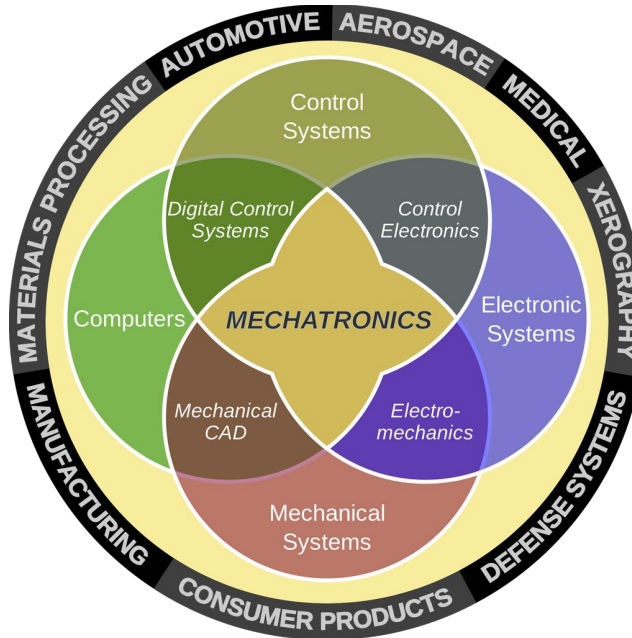

Figure 1. Mechatronics incorporates a mix of four disciplines.

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.

Hourly wages ($)

(a)

Employment (2018)

(b)

Hourly wages ($)

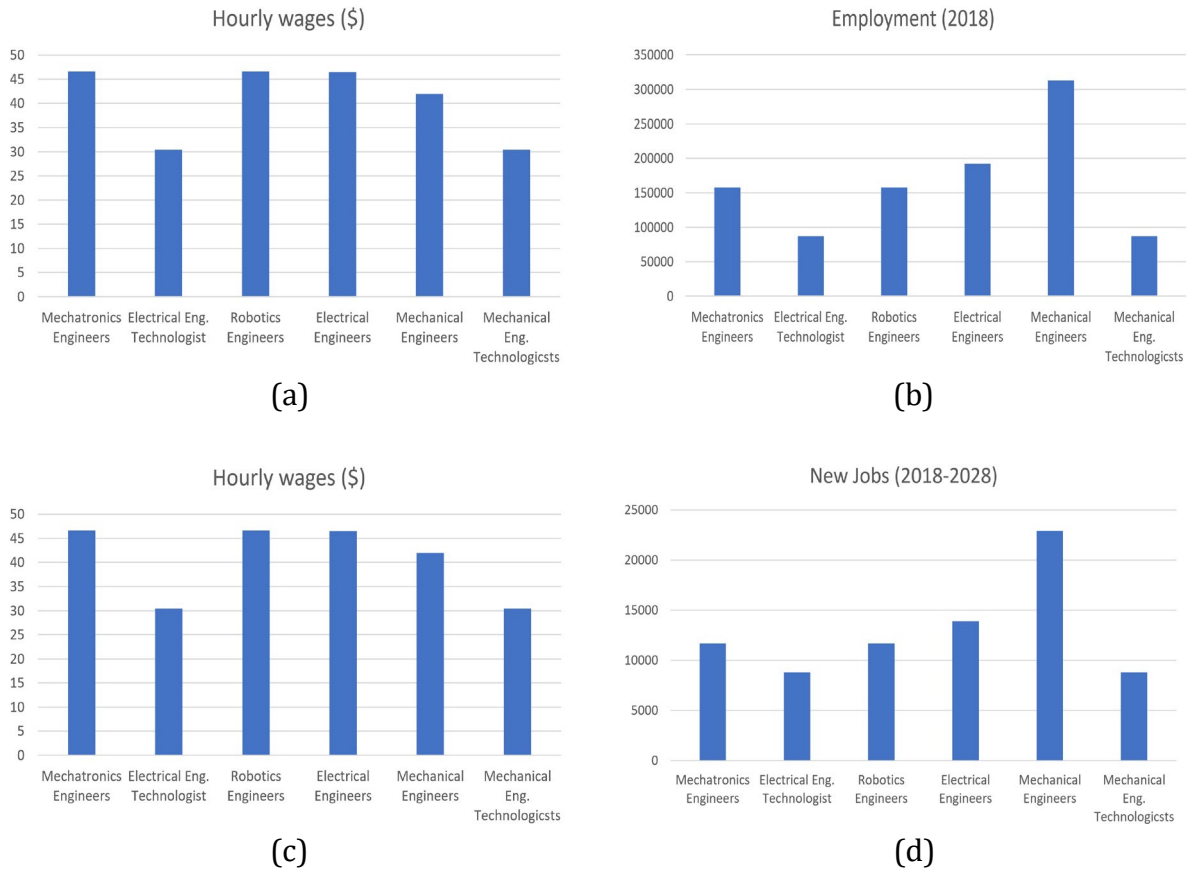

(c)

New Jobs (2018-2028)

(d)

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

We acknowledge that the BLS data presented here references job growth in *Mechatronics Engineering*, whereas the name of the degree program proposed here uses the more inclusive term *Mechatronics,* reflected in the language throughout this proposal. Our view, which we will continue to promote throughout rollout of the program, is that Mechatronics is an emerging interdisciplinary field that does not fit neatly in legacy categories of engineering, engineering technology, or computing. Since the BLS reporting does not recognize the stand-along term *Mechatronics*, we can only report what is given in Appendix A and summarized in the bar charts in Figure 2.1. The same situation applies to categorizations used by ABET (where we will seek accreditation through the Engineering Technology Accreditation Commission, or ETAC), and by the CIP codes from the National Center for Education Statistics, which puts all U.S. education programs in pre-defined categories. We seek to define a degree program which defies easy categorization but which nonetheless meets a critical and growing workforce need in industry.

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:
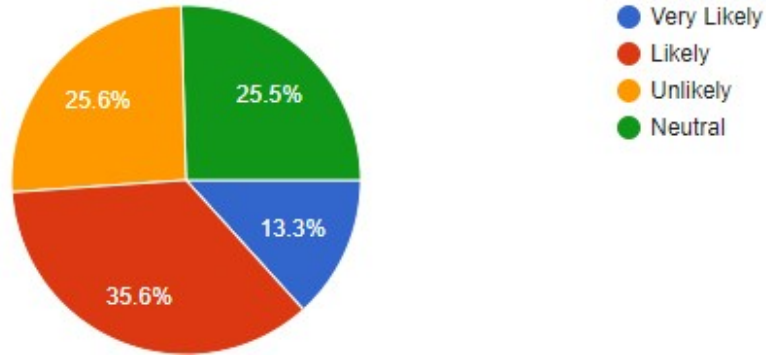
A. Would your company hire a Mechatronics graduate?
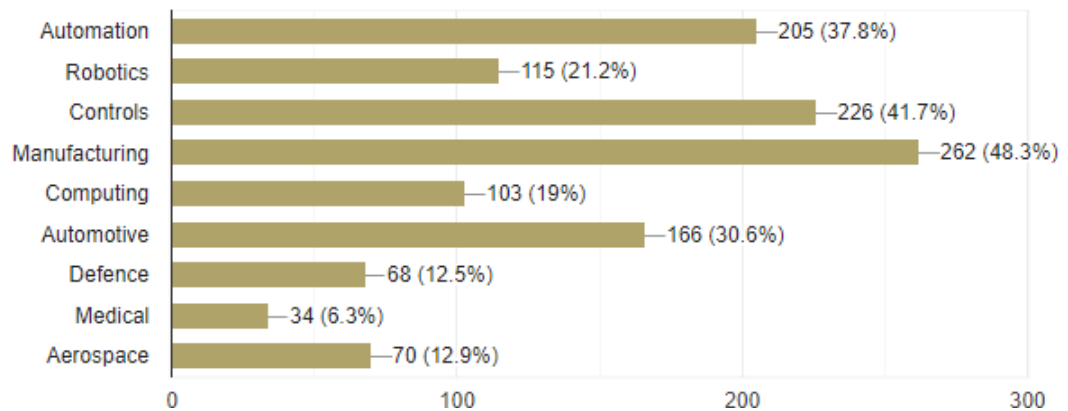
542 responses
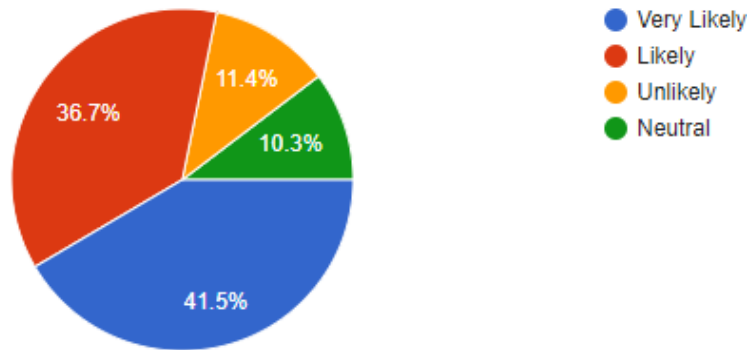
B. In the hiring process, would mechatronics graduates receive a priority over traditional electrical or mechanical graduates?

542 responses

- ● Very Likely
- ● Likely
- ● Unlikely
- ● Neutral

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

542 responses

Focus Area	Count (Percentage)
Automation	205 (37.8%)
Robotics	115 (21.2%)
Controls	226 (41.7%)
Manufacturing	262 (48.3%)
Computing	103 (19%)
Automotive	166 (30.6%)
Defence	68 (12.5%)
Medical	34 (6.3%)
Aerospace	70 (12.9%)

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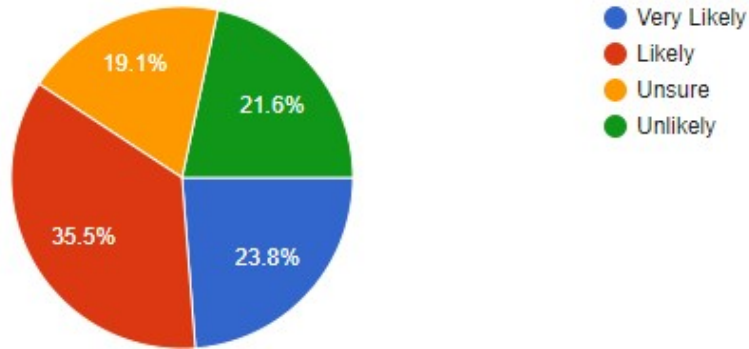
If you are currently enrolled in a Michigan Tech BS degree program, would you be interested in pursuing a minor in Mechatronics?

282 responses
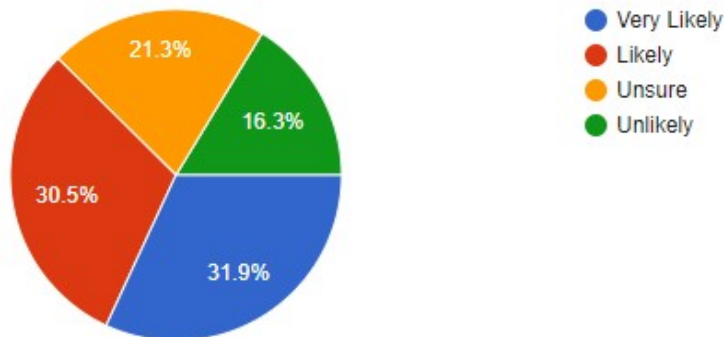
From the survey results, it is obvious that there is a strong interest in BS degree in Mechatronics among Michigan Tech students – 60% of students favored the degree, and another 62% would

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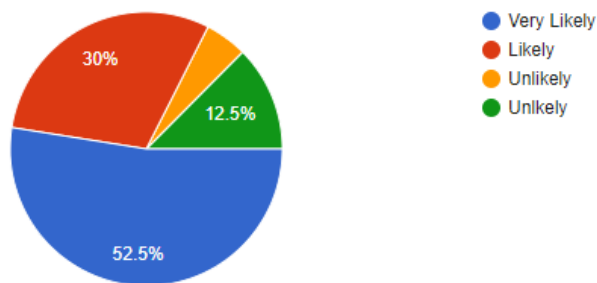
If you are currently enrolled in a two-year degree program at the community college, would you consider (upon the completion of your 2-year degree) to transfer the required credits to Michigan Tech to continue your degree pursuing the BS in Mechatronics at Michigan Tech?

40 responses

- Very Likely
- Likely
- Unlikely

30% 22.5% 47.5%
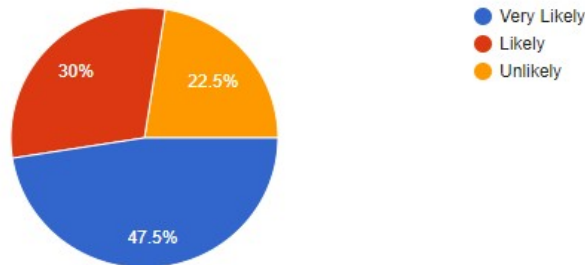
Even with the low response rate, it is clear that the interest in Mechatronics degree is high – 81% of outside to Michigan Tech students would highly consider to receive a BS in Mechatronics Degree from Michigan Tech. In addition, 78% of surveyed students would consider to continue their education at 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.
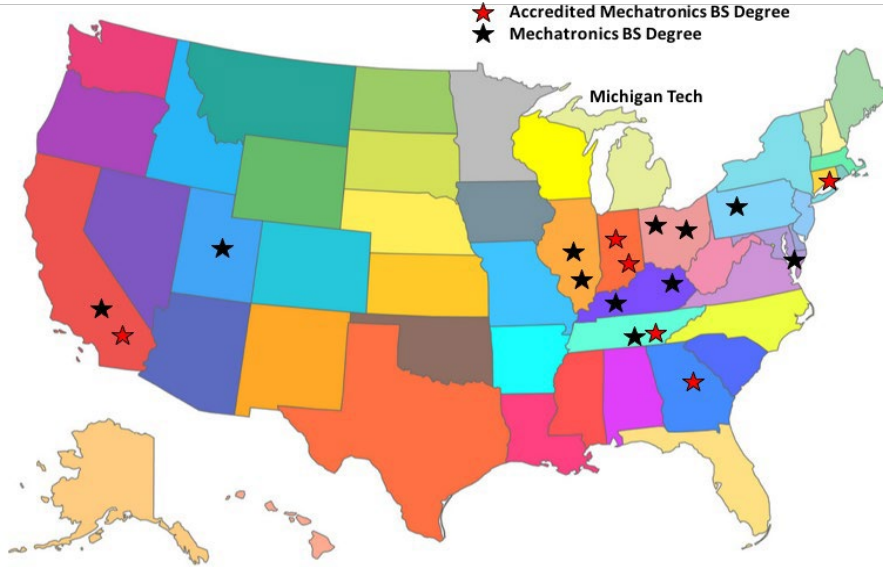
3.3. In the United States

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
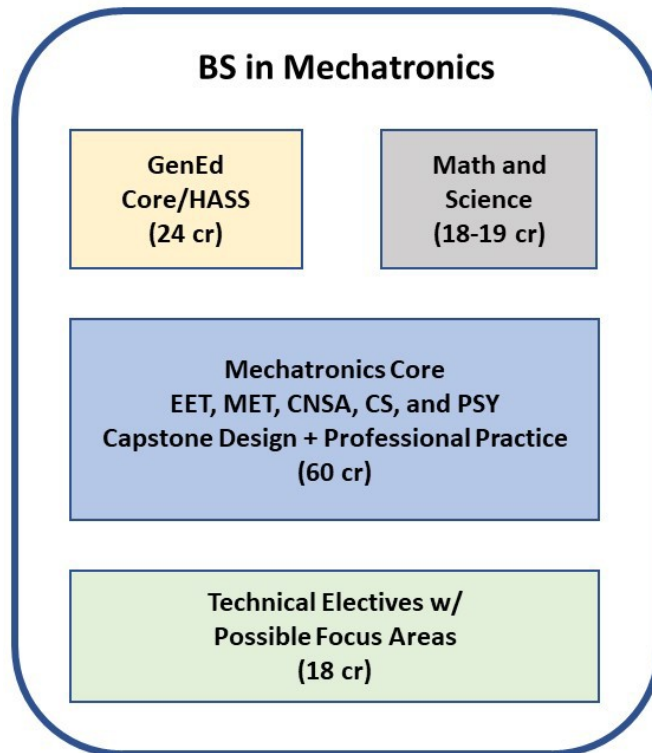
The figure above depicts the proposed structure of a new BS degree in Mechatronics. The minimum number of credits for the BS in Mechatronics is 120. The degree consists of General Education core and HASS courses (24 credits), math and science (18-19 credits), mechatronics core courses, which cover topics 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
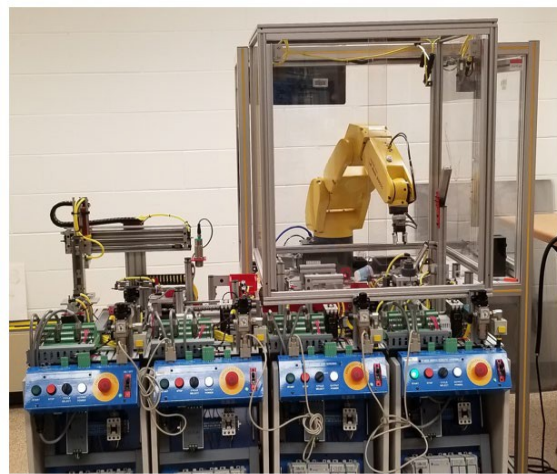
Figure 7: SoT Robotics Lab – Mechatronics assembly line retrofitted with FANUC LR 200iC industrial Robot

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*
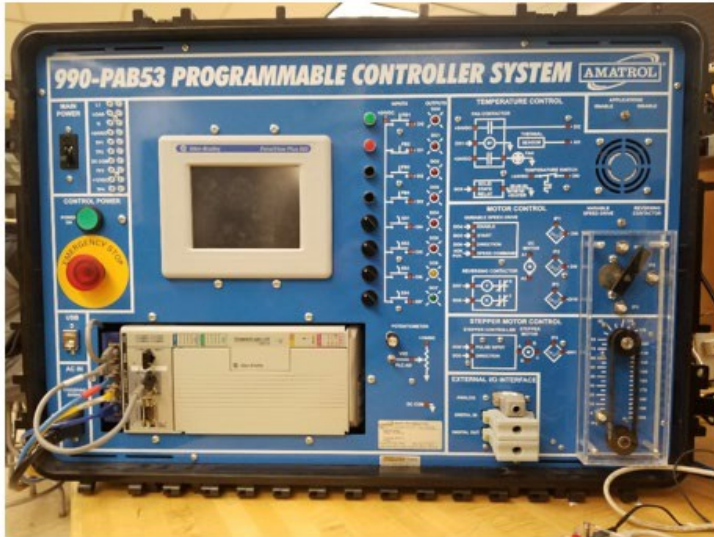

Figure 8 (b): SoT and ECE PLC Lab – *Process Control Systems*

990PAB53 Learning System comes with a mobile carrying case, 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.

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.
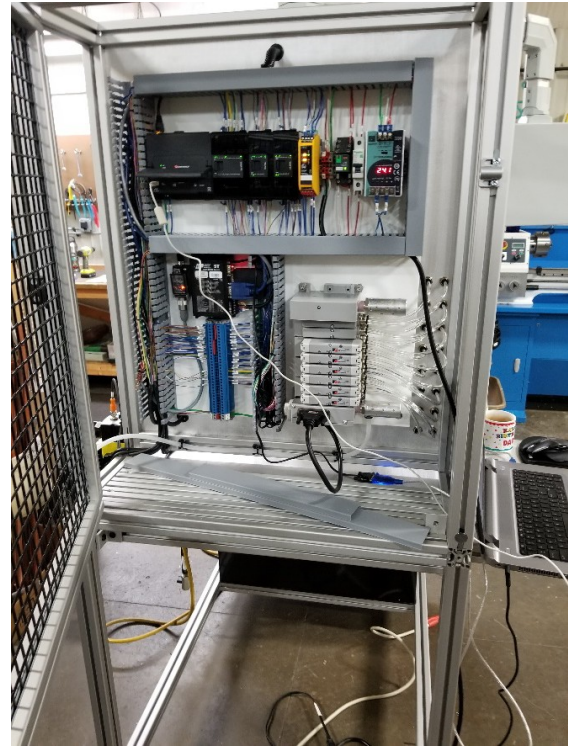
In addition to the developments in automation and controls, the College of Computing Electrical Machinery lab has been recently updated with new Amatrol electrical machine equipment. Seven new stations designated to teaching skills in AC and DC electrical machines and controls have been obtained and 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.
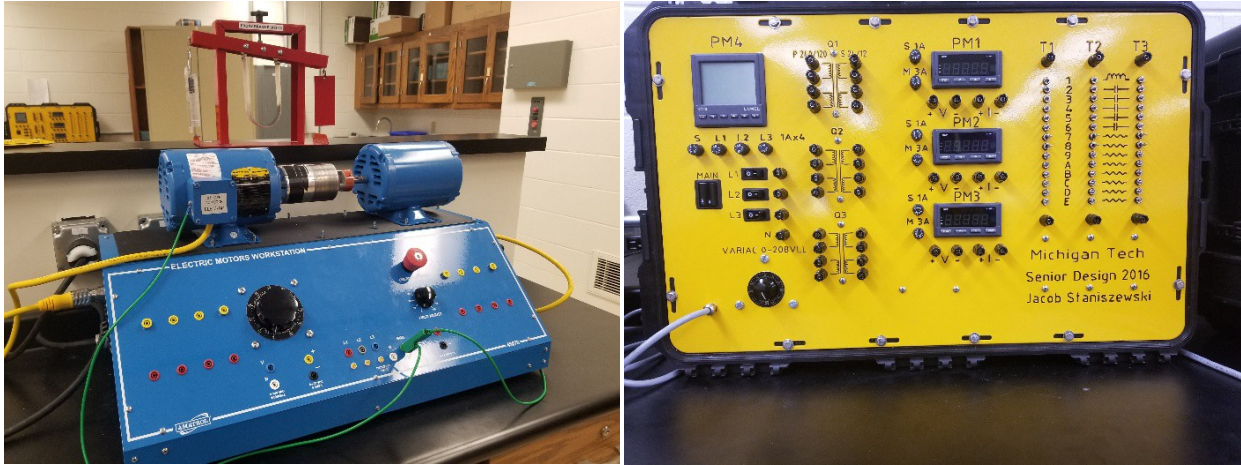
Availability of state-of-the-art industrial equipment is important to enable the teaching of critical skills that are very relevant to current industry needs. Currently, laboratory equipment associated with teaching introductory and advanced concepts of Programmable Logic Controllers is adequate for 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 (Senate Procedure 108.1.1, Proposal 51-04, Finance for New Degree Programs)

11.1 Relation to University's Strategic Plan:

Michigan Tech's strategic plan, Education, states for the Education goal that Michigan Tech will: "Provide a distinctive and rigorous action-based learning experience grounded in science, engineering, technology, business, sustainability, and an understanding of the social and cultural contexts of our contemporary world." The plan goes on to state that this is to be accomplished through three sub-goals: Student Learning, Transformative Education, and through Educational Programs. Under Student Learning, the strategic plan states, "Continually assess, re-

view, and improve programs and develop new offerings in emerging disciplinary and interdisciplinary areas." The Transformative Education sub-goal states, "Encourage and support high quality, innovative and effective instruction and experiences to enhance student learning." The Educational Programs sub-goal states, "Expand programs in response to social and economic needs and challenges."

There is a demand for Mechatronics graduates as the landscape of engineering and computing 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 engineer, engineering technologists, computing professionals, and 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 systems, mechanical systems, robotics, advanced controls, automation, computing, and cybersecurity fields. This new offering is fully aligned with the university's strategic plan.

11.2 Impact on University Enrollment:

Based on an initial assessment conducted using the survey for the students currently at Michigan Tech on the relevance of a BS degree in Mechatronics, 170 out of 280 students would enroll in the proposed degree program. Using an initial conservative rate of 20%, we estimate the proposed program to have approximately 35 degree-seeking students that would join Michigan Tech in any way. In order to understand the perception of the BS in 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 students from other universities and community colleges. This survey targeted two studies:

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

The results of the survey clearly showed that the interest in Mechatronics degree is high – 81% of students from outside Michigan Tech would strongly consider pursuing a BS in Mechatronics degree from Michigan Tech. In addition, 78% of surveyed students would consider continuing their education at Michigan Tech upon receiving their 2-year degree from a community college. The offering of a 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 student enrollment at Michigan Tech. This will create an additional influx of students into the BS in Mechatronics.

Considering all of the above, over the first three years we anticipate steady-state enrollment of 40-60 students including international and students from the other universities.

Considering the interdisciplinary nature of Mechatronics degree, various minors can be foreseen. The Department of Applied Computing is considering minors in: 1) Industrial Robotics and

2) Automation and Controls. Other minors can be developed upon the program evolution. In general, minors provide students with better credentials upon graduation and therefore can promote a better student retention at Michigan Tech. Availability of minors will also positively impact the enrollment in mechatronics courses.

The overall 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.

11.3 Impact on Resources Required by Department in Which the Program is Housed

This program is proposed without requesting additional resources in the Department of Applied Computing.

The following background information may be useful. The new Department of Applied Computing comprises three faculty groups: Computer Network and System Administration (CNSA), Mechatronics, Electrical, and Robotics Engineering Technology (MERET), and Health Informatics (HI). There is some overlap among faculty in the three groups. The CNSA group is responsible for the degree program BS in Computer Network and System Administration, and it shares responsibility for the degree program BS in Cybersecurity with the Department of Computer Science. The MERET group is responsible for the degree programs BS in Electrical Engineering Technology (EET), the MS in Mechatronics, and, if approved, the proposed BS in Mechatronics. The HI group is responsible for the degree program MS in Health Informatics, and the HI faculty also advise some PhD students in the interdisciplinary Computational Science and Engineering (CS&E) program.

A. Faculty lines. Existing faculty and departments at Michigan Tech (AC/MERET, AC/CNSA, MMET, ECE, CLS, and CS) have the expertise and existing course offerings to initially offer the proposed program without additional resources. With growth, faculty should be added in support of the coursework needed, in support of providing the needed capacity in technical coursework (see section 10.4).
B. MERET faculty and MERET student labs: The first 100 students enrolled in the program can be handled by the existing (including 2 new hires in 2020) MERET faculty and MERET laboratories.
C. Advising: Current EET, CNSA, HI, Cybersecurity, and Mechatronics students are advised by an academic advisor in the College of Computing. Once there are 300 additional students enrolled in the Department of Applied Computing (considering all of the degree programs stated in the paragraph above), one additional advisor will be needed as per NACADA guidelines.
D. Assessment: The BSEET program is an ABET-accredited undergraduate program and the MERET faculty have strong familiarity with continuous improvement of academic programs through assessment, and the associated administrative responsibilities.

11.4 Impact on Resources Required by Other Units Within the University.

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

The existing faculty at Michigan Tech in AC, MMET, and CS have the expertise and existing course offerings to initially offer the proposed program without additional resources. With the exception of two new EET and MET courses that will be developed, the curriculum is based on existing coursework at the university. As the program grows, instructional faculty and graduate teaching assistants will be needed in support of the needed courses and labs to augment the AC/MERET, MMET and AC/CNSA faculty in support of the Mechatronics core courses. This will assure the needed capacity in technical coursework required for the degree.

Student labs: Growth of this new program beyond approximately 45 students will require corresponding university investment in technical support, robotics laboratory space and equipment to handle the growth. The existing MERET robotics instructional space supports an undergraduate EET enrollment of 50. The MERET faculty have brought in $1.2M in funding over the past six years in support of the EET curriculum which includes a robotics laboratory and associated equipment. It is estimated that an approximate doubling of students who take the five EET courses in the curriculum (four mandatory courses, one of which is cross-listed with ECE, and one EET courses that is found optionally in the curriculum) from 50 to 100 can be handled with existing personnel and equipment but that growth beyond 100 students in the robotics and supporting courses offered by EET faculty will require investment to further increase capacity.

11.5 Assessment of the ability to obtain the necessary resources assuming requested funds are Obtained

There is no anticipated issue with resources; no funds are initially requested.

11.6 Past Proposals

The MERET group launched a new MS in Mechatronics in Fall 2019, when it was part of the CNSA/MERET/HI Division of the College of Computing. The presence of the proposed BS in Mechatronics degree will provide a smooth transition for the undergraduate students completing the program to advance in the graduate studies in Mechatronics. The existence of both undergraduate and graduate programs in the field of Mechatronics will, in turn improve the retention rate of the students at Michigan Tech.

The CNSA group launched a degree program BS in Cybersecurity jointly with the Department of Computer Science in the Fall of 2019.

11.7 Departmental Budget Contribution

The Department of Applied Computing will be recognized by the university as a cost center on July 1, 2020. The FY21 General Fund budget for salary, fringe benefits, SS&E, and start-up commitments for future hires in the Department, is $2.043M.

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

The two new proposed degrees BS in Mechatronics and BS in Robotics have different and distinctive educational opportunities for the students at Michigan Tech. Robotics Engineering degree provides students with the solid knowledge necessary for research and development of autonomous robotic solutions. On the other hand, the mechatronics curriculum places heavy emphasis on industrial robotics, automation and controls, and with substantial prominence on traditional and engineering computing. The mechatronics degree merges the knowledge from electrical, mechanical and computing disciplines providing students with the solid knowledge in industrial robotic solutions, automation, applied controls, and strong computing and computing security skills. The Mechatronics core also includes 12 credits of mechanical coursework which will provide significant background on mechanical aspects of manufacturing processes to the students pursuing the degree. Both degrees are very needed and provide distinct employment opportunities for the students upon graduation.

The approval of the BS Mechatronics would not preclude the development of a BS in Robotics Engineering or any other degree. Rather, the BS in Mechatronics program would provide additional revenue to the university by recruiting students with interests in engineering, engineering technology, and computing.

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 complexity. 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: February 5, 2020
Approved by: Dean's Council
Date: February 11, 2020
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

View report:	Summary	Details	Custom	

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

View report:	Summary	Details	Custom	

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

View report:	Summary	Details	Custom

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

View report:	Summary	Details	Custom

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

View report:	Summary	Details	Custom

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 Engineering Tech

View report:	Summary	Details	Custom

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.