Michigan Tech

Office Memo

Office of the Provost and
Senior Vice President for Academic Affairs

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

TO: Richard Koubek, President

FROM: Andrew Storer, Provost & Senior Vice President for Academic Affairs

DATE: May 31, 2024

SUBJECT: Senate Proposal 14-24

Attached is Senate proposal 14-24, “Establishment of a Doctor of Philosophy in Manufacturing Engineering” and a memo stating the Senate passed this proposal at their April 3, 2024 meeting. I have reviewed this memo and recommend approving the proposal and sharing with the Senate that the administration appreciates the content relating to resource needs for this program and anticipates resource allocation to be consistent with existing resourcing plans and the university budgeting process.

If you concur with my recommendation, the provost’s office will seek the following approvals.

X Board of Trustees
X Michigan Association of State Universities (MASU)
X Higher Learning Commission (HLC); screening required for all degree programs as well certificates

Programs cannot be fully advertised until all noted approvals are obtained. Limited advertising to make prospective students aware of the planned program may be conducted so long as any outstanding regulatory approvals are noted, e.g., "pending final administrative, state and Higher Learning Commission approval".

I concur X do not concur _____ with the provost’s recommendation as stated in this memo.

Richard J. Koubek Digitally signed by Richard J. Koubek
Date: 2024.06.04 16:36:37 -04'00'

Richard Koubek, President

Date

Michigan Tech

University Senate

DATE:	April 4, 2024
TO:	Richard Koubek, President
FROM:	Robert Hutchinson University Senate President
SUBJECT:	Proposal 14-24
COPIES:	Andrew Storer, Provost & Senior VP for Academic Affairs

At its meeting on April 3, 2024, the University Senate approved Proposal 14-24, "Establishment of a Doctor of Philosophy in Manufacturing Engineering." Feel free to contact me if you have any questions.

The University Senate of Michigan Technological University

Proposal 14-24

Establishment of a Doctor of Philosophy in Manufacturing Engineering

Submitted by: Manufacturing and Mechanical Engineering Technology (MMET) Department

I. Background:

The Manufacturing and Mechanical Engineering Technology (MMET) department currently offers an MS in Manufacturing Engineering which includes core manufacturing courses along with options for coursework that specialize in Industry 4.0 topics like additive manufacturing. The Manufacturing Engineering PhD program will emphasize research of the most viable and efficient processes used during fabrication, shaping, machining, and assembly and will provide an ability for students with an MS degree to further their domain knowledge and expertise in the field.

The MMET department was formed as a new department in the College of Engineering in fall of 2019. At the undergraduate level the MMET department administers the BS Mechanical Engineering Technology (MET) program and the Minor in Manufacturing Systems. MET students learn the fundamentals of machining, manufacturing processes, and quality control methods. With this manufacturing emphasis in the degree many employers hire MET students as Manufacturing Engineers, Process Engineers, Production Engineers, and Quality Engineers. There are approximately 200 undergraduate MET program students and eight faculty members associated with the department. The MMET department manages the MMET Machine Shop located in the M&M building. The MMET Machine Shop is used for several manufacturing courses, enterprise course fabrication, and for developing undergraduate projects. This lab facility is also a resource for faculty research project fabrication and testing that will be available for PhD students as well.

In addition to the MS in Manufacturing Engineering degree, the MMET department currently offers an online certificate in Manufacturing Engineering. The two graduate offerings include core manufacturing courses along with options for coursework that specialize in Industry 4.0 topics like additive manufacturing. Students pursuing this PhD can earn the MS in Manufacturing Engineering along the way. MMET department also supports the interdisciplinary MS in Mechatronics degree and associated certificates. The faculty in MMET have manufacturing industry experience, and most teach courses and conduct research in manufacturing. MMET faculty have a long record of advising graduate students from departments on campus inside and outside of the College of Engineering.

Basic Program Information

1. **Proposal date:** January, 2023.
2. **Proposer primary contact:** John L. Irwin, Professor/Chair, MMET department
3. **Program Degree Type:** PhD
4. **Program Title:** Doctor of Philosophy in Manufacturing Engineering

5. **Program Implementation Date:** Fall 2024.
6. **Program location/modality:** On campus
7. **New Target Student Population:** New Target Student Population
   The Manufacturing Engineering PhD will attract various degree majors that otherwise would not necessarily pursue research in manufacturing within a PhD in Mechanical Engineering because those generally are designed for students with a mechanical engineering degree. Students with degrees in biomedical, electrical, chemical, robotics or material science may desire to pursue advanced manufacturing research related to their area of specialty. But, the primary source of interest will be from manufacturing related program students.

   Recruiting will target the numerous accredited manufacturing bachelor's degree program students in the US at the undergraduate level, including (27) ABET EAC Manufacturing Engineering degrees and (28) ABET ETAC Manufacturing Engineering Technology degrees. Institutions in Michigan offering EAC or ETAC Manufacturing degrees are; Grand Valley, University of Michigan Dearborn, Lake Superior State, and Lawrence Tech. There are many other undergraduate programs with a manufacturing focus or minors within their departments like those at Michigan Tech (e.g. ME_EM, MMET, & Applied Computing).

   There are also several universities in Michigan offering master's programs in Manufacturing Engineering including Michigan Tech's MMET department MS degree that can serve as a pipeline into the PhD program. Others include Western Michigan University, Wayne State University, and the University of Michigan. Regionally, MS programs are offered at the University of Wisconsin-Stout, Illinois institute of Technology, and the University of Wisconsin-Madison. Other programs of note are Arizona State, and Clemson. The existence of these and other similar Manufacturing Engineering MS degree programs reinforce the need for this PhD, and will provide sources for potential recruiting of students.

   The marketing plan for the PhD program will target the Michigan Tech MS Manufacturing Engineering and related degree program students, as well as undergraduate students in several related majors. The Michigan Tech MS in Manufacturing Engineering had eight students enrolled in fall 2023 after just being introduced in fall 2021, and the related interdisciplinary program, MS in Mechatronics, had 46 students enrolled in fall 2023. The Graduate School will also be encouraged to actively market this degree with international students, especially those with an interest in manufacturing over traditional mechanical design research and development.

8. **General description and characteristics of program:**
   a. **Description:**
      Our goal is to prepare students at the doctoral level who can continue their research in post-doctoral training, assume positions in academia, industry, or governmental agencies and be prepared to grow into positions of advanced manufacturing leadership. This goal is supportive of Michigan Tech's strategic plan's goals for education, scholarship, and people:

      Education: Expand programs in response to social and economic needs and challenges.

- Increase both scholarly productivity and number of doctoral and master's degrees awarded.

Scholarship: Grow research, scholarship, and creativity.

- Increase external support for research, scholarly, and creative activities, including leadership of interdisciplinary multi-institutional collaborations.

People: Foster and support an exceptional and diverse community of students, faculty, and staff.

- Optimize numbers of tenured, tenure-track, and instructional-track faculty and staff to foster growth of University programs.

Courses will allow for specialization in Industry 4.0 topics like additive manufacturing, Manufacturing Systems and Operations, Product Tooling and Assembly Engineering, Quality Engineering, and Advanced Materials and Manufacturing Processes. The Manufacturing Engineering PhD program will emphasize research of the most viable and efficient processes used during fabrication, shaping, machining, and assembly (see Figure 1).

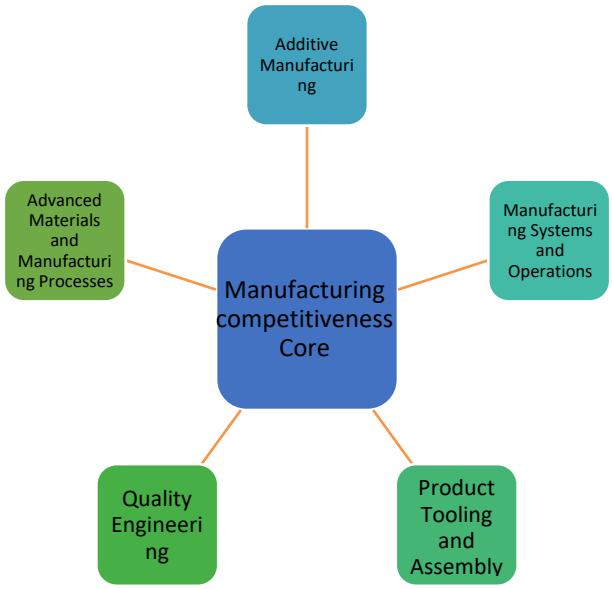

Figure 1. MS & PhD core and emphasis areas

Michigan Tech faculty members possess considerable expertise in advanced manufacturing engineering fields. Current research projects in the MMET Department include work in Whirlpool - Refrigerator Door Gasket Verification Fixture, Machinability of Solution Strengthened Ferritic Ductile Iron, LIFT- IMP Machining Samples, Manufacturing Workforce Development - Fluid Power Training, MET Students in the Pilot-Scale Metal/Steel Processing Facilities at Michigan Tech, and CTE Mechatronics Education. Interdisciplinary collaborative faculty from the Colleges of Engineering, Business, and Computing have expertise in printed circuit board production, systems simulation, robotics, biomechanics, industrial automation, and mechatronic systems among others.

b. **Characteristics:**

The National Center for Education Statistics (NCES) defines the detail for CIP Code 14.3601, Title: Manufacturing Engineering as:

> "A program that prepares individuals to apply scientific and mathematical principles to the design, development, and implementation of manufacturing systems. Includes instruction in materials science and engineering, manufacturing processes, process engineering, assembly and product engineering, manufacturing systems design, and manufacturing competitiveness."

The Four Pillars of Manufacturing Engineering were developed by the Society of Manufacturing Engineers (SME) through its Center for Education and revised by the SME Manufacturing Education and Accreditation Committee. Chair of this Committee, Dr. Irwin, has led the revision of the Four Pillars process that started in 2021 preparing for its dissemination in June 2024. The Four Pillars model builds on the topics in the SME body of knowledge for the certification of manufacturing engineers. The Four Pillars model defines topics in the categories of:

1) Materials and manufacturing processes;
2) Product, tooling and assembly engineering;
3) Manufacturing systems and operations; and
4) Manufacturing competitiveness.

The graphic representation of the Four Pillars is depicted as a structure including foundation, and the supporting pillars (see Figure 2).

The Four Pillars is used to guide the research areas for this manufacturing engineering PhD degree. Faculty in the MMET department have expertise in each of the Four Pillars categories that will support the student's research while pursuing their degrees. The categories in the Four Pillars cross disciplines that will lead to collaborations with dissertation committee support from faculty across the university. For instance, the Materials and Manufacturing Process category is associated most closely with the MSE Department research interests, Product Tooling and Assembly Engineering with ME-EM and ECE Departments, Manufacturing Systems and Operations with ChE, Applied Computing, and CS, while the Manufacturing Competitiveness category is aligned with research areas in Engineering Management.

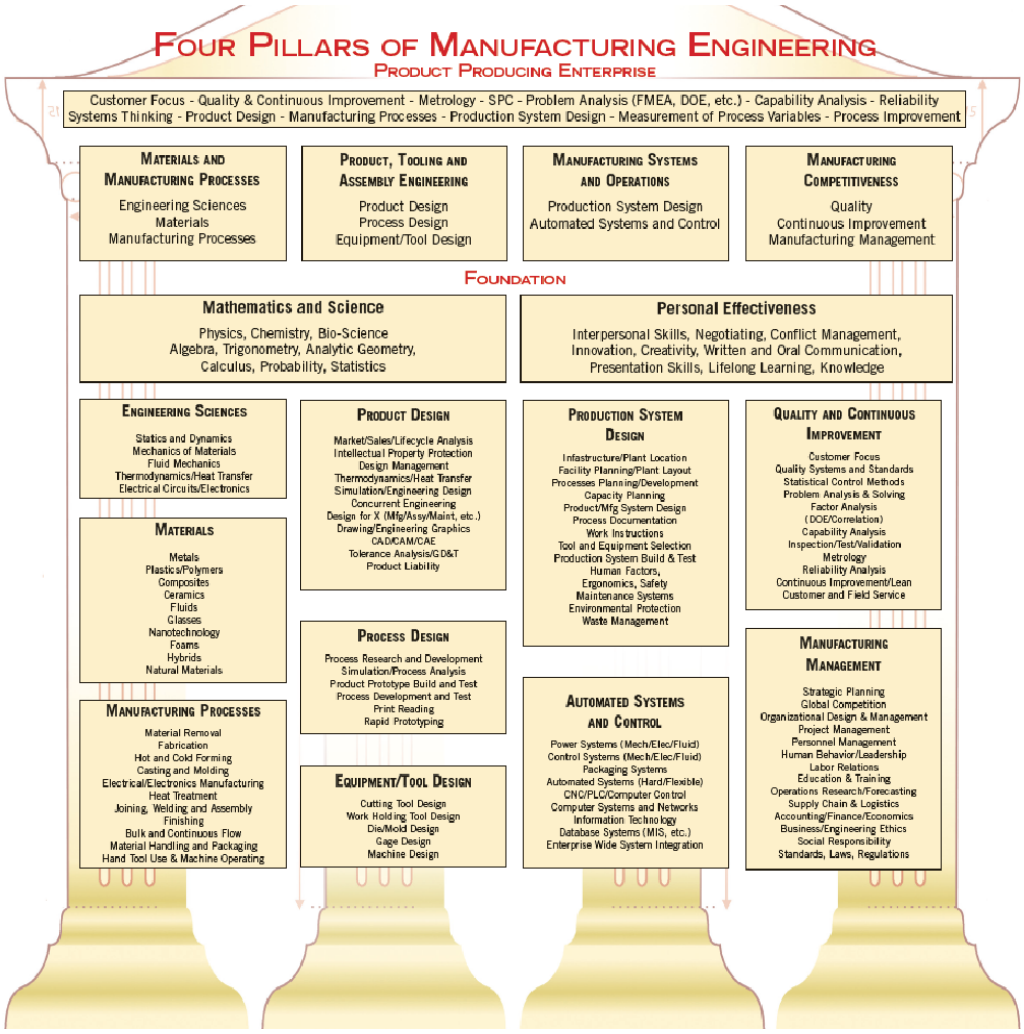

Figure 2. SME Four Pillars

9. Rationale:

a. Need:

Designs that are realized by engineers need to be manufactured with the end goal of producing a better product at a lower cost. This degree will cut across traditional disciplines (e.g., material science, mechanical engineering, electrical engineering, robotic engineering, biomedical engineering, and chemical engineering, etc.) to make advancements in manufacturing processes for forming, joining, casting, molding, producing composites, micromachining, and additive methodologies used in those disciplines.

The 2023 NAE Report[1], "Infusing Advanced Manufacturing into Undergraduate Engineering Education", is a consensus report of the National Materials and

[1] National Academies of Sciences, Engineering, and Medicine. 2023. Infusing Advanced Manufacturing into Undergraduate Engineering Education. Washington, DC: The National Academies Press. https://doi.org/10.17226/26773

Manufacturing Board, Division on Engineering and Physical Sciences, and National Academy of Engineering. The report has recommendations aimed at undergraduate engineering education's lack of exposure to or teaching about the use of advanced manufacturing technologies (or manufacturing technologies in general), and that few students are prepared to design for those technologies. This has implications for Manufacturing Engineering PhD programs, because for higher education institutions to educate undergraduate students there is the need for manufacturing engineering faculty who are experts in advanced manufacturing to deliver the material.

The recommendation from the NAE report is presented in two categories, which include those for undergraduate engineering education and for industry and government. The recommendations for education suggest that all engineering disciplines should cover realization of designs and that professional societies should advocate that accreditation criteria should include manufacturing. The report advocates for industry sponsored experiential learning throughout the engineering curriculum and that capstone designs should emphasize advanced manufacturing. The recommendations for industry and government are that the DOD and NSF should support programs that facilitate the collaboration of industry and academia. One example is that NSF should sponsor projects to develop advanced manufacturing curricula. It will be necessary to have more manufacturing engineering PhDs to accomplish these goals that are of great interest to the nation's defense industrial base.

b. Funding:

There are several federal funding sources for manufacturing engineering research. Some of those funding agencies are the National Science Foundation (NSF), Department of Defense (DOD), and the National Institute of Standards and Technology (NIST) that solicit proposals regularly. The NSF FY23 program titled, Future Manufacturing (FM), with the funding amount of $27M is aimed to support research in new manufacturing technologies and education to grow production and employment in the US manufacturing sector. The DOD Manufacturing Technology (ManTech) Program FY23/24 is seeking proposals for the Manufacturing Science and Technology Program (MSTP) project. The MSTP works to stimulate the early development of manufacturing to achieve the largest cost-effective impact. For example, one priority area is Solid State Joining (SSJ) which is a manufacturing technology used for mechanical joining with the goal of removing risks associated with design, manufacturing, inspection, and use of SSJ components. The Advanced Manufacturing Technology Roadmap (MFGTech) Program is run by the NIST Office of Advanced Manufacturing. MFGTech has funding opportunities to establish new industry-driven consortia that address high-priority research challenges to grow advanced manufacturing in the US.

c. Career Outlook:

The NCES CIP Code 14.3601 is defined as Manufacturing Engineering, but the U.S. Bureau of Labor Statistics does not have an occupational category specifically for this

title. According to Recruiter.com[2] the career outlook shows 14% growth for manufacturing engineering jobs through 2030 and predicts that 35,600 new jobs will be filled by 2029, resulting in an annual increase of 1.36 percent over the next few years. These manufacturing job increases will require additional faculty at academic institutions holding PhD degrees to provide manufacturing related education, as well as the need for research engineers in industry to continue to accelerate the growth of innovative technologies.

The BLS shows that the median salary for engineering post-secondary teachers is $80,840 per year, and that this occupation has projected 8% (Faster than average) change in employment from 2022 to 2032 compared to the average growth rate for all occupations of 3 percent. According to various online employment sources, the average pay scale for manufacturing engineers with a PhD is $106-110k. Also, the skills that are most desired are in process engineering.

The National Center for Science and Engineering Statistics (NCSES), within the NSF serves as a clearinghouse for the collection, interpretation, analysis, and dissemination of objective science and engineering data. The data indicates that over the last 20 years there has been no significant change in the percentage of Industrial and manufacturing engineering research doctorate recipients in the US in relation to all engineering PhD graduates (see Table 1).

Furthermore, the category of Industrial and manufacturing engineering is broken down into four subcategories of Industrial engineering, Industrial and systems engineering, Operations research, and Systems and manufacturing engineering. The Systems and manufacturing engineering doctorate recipients make up the second smallest percentage of this category at 134 (20.5%), which has the potential to increase with graduates from this PhD program. This group is the least diverse in terms of gender at 14.2 % female (see Table 2). To increase the diversity of Systems and manufacturing engineering PhD recipients there is an opportunity to recruit from the MMET department Manufacturing Engineering MS degree which is currently 37.5% female.

Table 1. NCSES Research doctorate recipients, by historical major field of doctorate: Selected years, 2002–2022

Field of doctorate	Engineering	Industrial and manufacturing engineering
	Number/percent	**Number/percent**
2002	5,081 /12.7	230/0.6
2007	7,749/16.1	279/0.6
2012	8,469/16.6	226/0.4
2017	9,776/17.9	249/0.5

[2] https://www.recruiter.com/careers/manufacturing-engineers/outlook/

2022	11,530/20.0	381/0.7

Table 2. NCSES Research doctorate recipients, by detailed field of doctorate and sex: 2022

Field of doctorate	Total	Male	Female	% female
Industrial engineering and operations research	**655**	**469**	**186**	**28.4**
	Total/%			
Industrial engineering	211/32.2	144	67	31.8
Industrial and systems engineering	127/19.4	84	43	33.9
Operations research	183/27.9	126	57	31.1
Systems and manufacturing engineering	**134/20.5**	**115**	**19**	**14.2**

10. Related programs:

Often a PhD degree is achieved in an area other than manufacturing such as mechanical engineering, with a focus in manufacturing. This degree path is more commonly found in universities throughout the US. For instance, Michigan Tech offers a Mechanical Engineering PhD with a focus in manufacturing. Due to this general practice, many researchers with the title of Manufacturing Engineer do not have a degree in manufacturing. There is a shortage of Manufacturing Engineering PhD programs dedicated solely to advance research and innovation in advanced manufacturing topics.

For instance, manufacturing is one of thirteen different research areas of specialization in the UofM Mechanical Engineering PhD program. The UofM manufacturing research group has fourteen related faculty with 10 different specialty areas. UofM has a long history of manufacturing going back to 1921 with the first Production Engineering Department in the US that later merged into the Mechanical Engineering Department. Facilities include a PANDA laser metal powder bed fusion machine, friction stir welder, and a Gleebie System physical simulation machine. There are several 500 level graduate courses offered in three areas which are Machine Design and Mechatronics, Manufacturing Processes, and Manufacturing Systems & Data Analysis. PhD research is grouped into areas of Cyber-Physical Systems & Smart Manufacturing, Additive Manufacturing, Machine and Part Design, Low Carbon Materials Processing, Biomedical/Nano/ICME Manufacturing, and Forming and Joining.

Additional regional doctoral programs that have Manufacturing Engineering specializations are the University of Illinois (Illinois) at Champaign and Northwestern University in Evanston, Illinois. Illinois has two PhD options in the department of Industrial & Enterprise Systems Engineering which are a PhD in Industrial Engineering, and a PhD in Systems and Entrepreneurial Engineering. Each program requires 32 hours of coursework beyond the MS degree, plus 32 hours of thesis research. Northwestern has a Mechanical Engineering PhD with seven areas of research including the Advanced Manufacturing research area. The Advanced Manufacturing research subtopics are Additive Manufacturing Processes and Systems, Deformation-based Manufacturing Processes and Systems, Micro/nano and Precision Manufacturing, Physics-based Data-driven Process Design and Control, and Digital Twins in the Connected World.

A standout program in the US is the Manufacturing Engineering PhD program at Arizona State University. The degree requires 84 total credits, which include 30 credits maximum from a previous MS degree, 15 credits in coursework, 12 credits minimum in research, 12 credits in dissertation, and the remaining as electives. Research thrusts are described as Digital Manufacturing, Additive Manufacturing, and Robotics and Automation which are supported by eighteen research faculty.

Within all the PhD degrees that fall under the manufacturing engineering discipline, the prerequisites are fairly common. The programs are primarily intended for individuals who possess a BS or MS degree in a technical field such as manufacturing engineering or closely related field, and possess a grade point average of 3.0 or higher. The Graduate Record Exam (GRE) is not required in all instances.

11. Projected Enrollment:

We anticipate that two students will enter the program in FY25 & FY26. Thereafter, we expect three new students per year. Within seven years the program will have 14 students and average two PhDs awarded annually with the eventual goal of five per year to be sustainable (see Table 3).

Table 3. PhD Anticipated Enrollment

Enrollment	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY##
Attrition = 25%>yr.3 Planning	Planning and recruiting							
New students		2	2	3	3	3	3	3
Returning students			2	4	6	7	10	11
Total enrollment		2	4	7	9	10	13	14
PhDs awarded					1	1	2	2

At least one student will be supported with a GA allocation; remaining students will be supported by external research funds; and the remainder will be self-supported. External

funding is anticipated to come primarily from federal agencies of NSF and DoD as discussed previously in the Rationale section.

12. Specialized Accreditation Requirements:

None.

13. Professional Licensure Requirements

None.

Curriculum Details

14. Learning Goals:

Upon graduation students will be able to:

1. Conduct research aimed at analyzing and formulating innovative technologies to advance the manufacturing body of knowledge.
2. Communicate effectively in written, graphic, and oral formats for audiences in industry, academia, and research.
3. Apply responsible, legal, and ethical codes of conduct to uphold and advance the integrity of the manufacturing engineering profession.

15. Assessment Plan

Each learning outcome is aligned with multiple performance indicators that will be assessed using rubrics. The assessment data will be analyzed to determine the percentage of students attaining the learning outcomes to determine if the target has been met. Action items will be developed based on the assessment data analysis and department feedback for continuous improvement.

16. Scheduling plans:

The program will be a regular on-campus offering. The 2024-2025 academic year will be used for student recruiting. All core courses will be offered regularly (either annually or biennially), beginning Fall 2024.

17. Curriculum design:

The requirements for the proposed degree follow University guidelines. There are 16 hours of core courses for students with a bachelor's degree that can be taken as electives by students with a master's degree with approval from an advisor. There are 12 credits minimum of dissertation research or practicum credit required. Maximum of 12 credits may be at the 3000 or 4000 level (see Table 4).

Table 4. PhD credits Required

Course requirements	**Credits required with a Bachelor's degree**	**Credits required with a Master's degree**
Core courses	16	0

Electives	14-32	0-18
Dissertation Research	12-30	12-30
Total	60	30

Core Courses: Bachelor's degree students take the 16 credits from this list. Master's degree students can include the 16 credits (with advisor approval) as electives where appropriate.

MA 5701 - Statistical Methods (3)
MFGE 5000 - Organizational Leadership (3)
MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
MFGE 5200 - Industry 4.0 Concepts (3)
MFGE 5400 – Industrial Safety (1)
MFGE 5010 – Professional Engineering Communication (3)

Manufacturing Emphasis Area Electives: The remaining courses are subject to advisor approval, with the limitation of a maximum of 12 credits at the 3000-4000 level. Example courses are shown below; other courses/areas may be suitable as well.

- **Additive Manufacturing**
- **Manufacturing Systems and Operations**
- **Product Tooling and Assembly Engineering**
- **Quality Engineering**
- **Manufacturing Sustainability**
- **Advanced Materials and Manufacturing Processes**

Additive Manufacturing
MFGE 5300 - Design for Additive Manufacturing (3)
MFGE 5400 - Additive Manufacturing Lab (3)
MEEM 5695 – Additive Manufacturing (3)

Manufacturing Systems and Operations
MEEM 5656 - Advanced Production Planning (3)
BA 5610 - Operations Management (3)
MET 4355 - Industrial Systems Simulation (3)
MET 4510 - Lean Manufacturing and Production Planning (3)
MET 4585 - Facilities Layout and Safety Design (3)
EET 5373 - Advanced Programmable Controllers (4)
SAT 4343 - Network Engineering (3)

Product Tooling and Assembly Engineering
MET 4550 – Computer Aided Manufacturing (3)
Or

MEEM 4430 - Advanced Computer Aided Design and Manufacturing Methods (3)
MEEM 5670/ENG5670 - Experimental Design in Engineering (3)

Quality Engineering
MEEM 5650 - Advanced Quality Engineering (3)
MEEM 5655 – Introduction to Lean Manufacturing (3)
MEEM 5670 – Experimental Design in Manufacturing (3)

Manufacturing Sustainability
ENG 5515 - Introduction to Sustainability and Resilience (3)
ENG 5525 - Systems Analysis for Sustainability and Resilience (3)
ENG 5540 - Sustainable Forest-Based Biofuel Pathways (3)

Advanced Materials and Manufacturing Processes
MET 4780 - Advanced Manufacturing (3)
MET 4377 - Applied Fluid Power (3)
MET 4378 - Advanced Hydraulics: Electro-hydraulic Components & Systems (3)
MET 5400 - Key Factors of Holistic Safety (1)
MSE 5100 - Introduction to Materials Science and Engineering with Advanced Topics (3)
MSE 5400 - Statistical Quality Control in Materials Manufacturing (3)
EET 5144 - Real-Time Robotics Systems (3)
EET 5147 - Industrial Robotic Vision System and Advanced Teach Pendant (3)

Other Requirements: Students will complete all of the University milestones for a PhD

- Pass Qualifying Examination
- Pass Research Proposal Examination
- Prepare and Submit Approved Dissertation
- Pass Final Oral Defense

18. New course descriptions:

MFGE 6999 – Dissertation Research (12-30 credits)
Fundamental and applied research in Manufacturing Engineering. Taken by doctoral students in partial fulfillment of the PhD research requirement.

19. Model Schedule

Table 5. 30 Credit Coursework MS plus 30 Credit PhD Research

Year 1- fall semester: 9 credits	**Year 1- spring semester: 9 credits**
MFGE 5000 - Organizational Leadership (3)	Emphasis Area Course (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
MFGE 5010 - Professional Engineering Communication (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
Year 2- fall semester: 9 credits	**Year 2- spring semester: 9 credits**

MFGE 5400 – Industrial Safety (1)	Emphasis Area Course (3)
Emphasis Area Course (3)	MFGE 6999 (6)
Emphasis Area Course (3)	
Emphasis Area Course (2)	
Year 3- fall semester: 9 credits	**Year 3- spring semester: 9 credits**
MFGE 6999 (9)	MFGE 6999 (9)
Year 4- fall semester: 6 credits	
MFGE 6999 (6)	

Table 6. 30 Credits Report MS plus 30 credits PhD research

Year 1- fall semester: 9 credits	**Year 1- spring semester: 9 credits**
MET 5000 - Organizational Leadership (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
Emphasis Area Course (3)	MEEM 6010 - Engineering Research Communication (3)
Year 2- fall semester: 9 credits	**Year 2- spring semester: 9 credits**
Emphasis Area Course (3)	MFGE 5999 - Graduate Research in MfgE (3)
Emphasis Area Course (3)	MFGE 5400 – Industrial Safety (1)
MFGE 5999 - Graduate Research in MfgE (3)	MFGE 6999 (5)
Year 3- fall semester: 9 credits	**Year 3- spring semester: 9 credits**
MFGE 6999 (9)	MFGE 6999 (9)
Year 4- fall semester: 7 credits	
MFGE 6999 (7)	

Table 7. 30 Credits Thesis MS plus 30 credits PhD research

Year 1- fall semester: 9 credits	**Year 1- spring semester: 9 credits**
MET 5000 - Organizational Leadership (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
Emphasis Area Course (3)	MEEM 6010 - Engineering Research Communication (3)

Year 2- fall semester: 9 credits	**Year 2- spring semester: 9 credits**
Emphasis Area Course (3)	MFGE 5999 - Graduate Research in MfgE (4)
MFGE 5999 - Graduate Research in MfgE (6)	MFGE 5400 – Industrial Safety (1)
	MFGE 6999 (4)
Year 3- fall semester: 9 credits	**Year 3- spring semester: 9 credits**
MFGE 6999 (9)	MFGE 6999 (9)
Year 4- fall semester: 6 credits	
MFGE 6999 (6)	

20. Program specific policies, regulations and rules:

No special regulations and rules

21. Faculty resumes:

The MMET faculty that will teach the graduate courses are listed, but all MMET faculty with graduate faculty appointments will be eligible to advise PhD students. Each has five plus years of experience in the manufacturing industry in areas of: operations/facilities management, process engineering, quality management, plant engineering/maintenance supervision, and manufacturing engineering. Faculty have education in leadership studies, organizational leadership and quality, manufacturing operations, mechanical engineering technology, and mechanical engineering.

Table 8. MMET Faculty

Faculty Teaching with link to webpage	**Link to Webpage**	**Course(s)**
Scott Wagner, PhD Associate Professor	Scott Wagner	MET 5400 - Key Factors of Holistic Safety (1), MET 4510 - Lean Manufacturing and Production Planning (3), MET 4585 - Facilities Layout and Safety Design (3)
David Wanless, PhD Associate Teaching Professor	David Wanless	MFGE 5000 - Organizational Leadership (3), MET 4780 - Advanced Manufacturing (3), MFGE 5400 – Industrial Safety (1), MET 4355 - Industrial Systems Simulation (3)
Nicholas Hendrickson, MS Professor of Practice	Nicholas Hendrickson	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3), MFGE 5300 - Design for Additive Manufacturing (3), MFGE 5400 - Additive Manufacturing Lab (3), MET 4550 – Computer Aided Manufacturing (3)
Kevin Johnson, MS Assistant Teaching Professor	Kevin Johnson	MET 4377 - Applied Fluid Power (3), MET 4378 - Advanced Hydraulics: Electro-hydraulic Components & Systems (3)

David Labyak, PhD Assistant Professor	David Labyak	MFGE 5200 - Industry 4.0 Concepts (3)

Resources Needed

22. Library and other learning resources:

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

Since this degree builds on the foundation of undergraduate degrees in MET, ME-EM, and MSE, additional library and learning resources are expected to be minimal.

23. Suitability of existing space, facilities, and equipment.

The future of manufacturing involves digital technologies as well as physical equipment needs. For instance, Simulation/Process Analysis/Digital Twin is utilized for courses in the Manufacturing Systems and Operations category using software packages such as Witness Horizon by Lanner (currently available) for simulating industrial systems. The software tools from Siemens, Dassault Systemes, and others that create a digital thread throughout the product lifecycle will need to remain current and available. In addition, advanced manufacturing relies heavily on the evolving computing technologies for artificial intelligence, machine learning, machine vision, data analytics, and others that support Industry 4.0. This program, therefore, represents opportunities for collaboration with other academic units.

The MMET Machine Shop is fully equipped with manual and CNC equipment, as well as additive manufacturing equipment. Equipment needed can be used for undergraduate as well as graduate student research (see Table 6). This equipment can be purchased as lab expenses, faculty startup, and/or partially funded with the online return from graduate student tuition. The online return amounts were FY22 $27,921, FY23 $99,310, and fall 23 expected return is $27,556. The entire return cannot be used for equipment purchases because there are overhead costs for faculty overload instruction, adjunct teacher payroll, and graduate program director stipend costs.

The College is committed to supporting the development and implementation of the manufacturing engineering PhD program.

Table 9. Equipment Needs

Research Category	**Equipment Description**	**Vendor**	**Approx. Cost**
Machinability Studies	CNC multi axis lathe	Haas	200k
	CNC mill with high-speed spindle	MSC	16k

	Machining forces - in spindle force load cells	Kistler	10k
Additive Manufacturing	J8 polymer printer	Stratasys	TBD
	Desktop metal binder jet printer	Markforged	138k
	robot welding cell	Fanuc	TBD
Advanced Manufacturing	Plastic injection mold machine	APSX	13.5k
	Laser table / engraver	Boss Laser	8.5k
	Shadowgraph, CMM 30-100k, profilometer	Mitutoyo	10k
	HVAC unit ET 101 Simple compression refrigeration circuit	G.U.N.T.	6k

24. Program costs:

Marketing is a cost that will be absorbed under the general SS&E budget for the department and college. No other additional costs are associated with this program.

108.1.2: Criteria for Financial Evaluation of Proposed Academic Programs

1. **Relation to University Strategic Plan:**
   The financial implications of this new program align with the University Strategic Plan goals for education, scholarship and people. This is addressed in Section 8.a.

2. **Impact on University Enrollment:**
   The spring 2024 enrollment in the Manufacturing Engineering MS degree is ten students after being initiated in Fall 2022 (after three semesters). The MET undergraduate program in the unit has 198 students. MMET is associated with the interdisciplinary Mechatronics undergraduate degree program (59 students) and the Mechatronics MS (49 students). This PhD will draw from these existing programs as well as from outside Michigan Tech. This PhD program is projected to have similar growth as compared to these existing programs. This is addressed in Section 10 & 11.

3. **Impact on Resources Required by Department in Which the Program is housed:**
   The newly added programs have had a positive impact on resources. Two faculty positions have recently been added in MMET, a Professor of Practice and an Assistant Teaching Professor. In addition, two tenure-track positions are currently in the search phase, one in the MMET department and one shared position to support the Interdisciplinary Mechatronics programs. MMET has a Parker Lab School designation receiving yearly funding to support the expansion of the Fluid Power courses initiated with these new degree programs. The Manufacturing Engineering courses have a large enrollment outside of the ten students enrolled in the program. The core Manufacturing Engineering degree has five online courses offered in the MMET Department. These courses average approximately 20 students each per semester. Many of these students are coded as online students that provide a tuition return.

   The online return funds support the Graduate Program Director workload in reviewing applications, graduate student advising and program assessment. These online returns also support an adjunct faculty member that typically teaches a Professional Practice Seminar and an Applied Dynamics course in both Fall and Spring semesters. This has helped to support the addition of the new programs. The Applied Computing Department in the College of Computing might be impacted because of the interdisciplinary nature of the Mechatronics programs. For instance, the cost of marketing, recruitment and senior capstone support is usually shared for initiatives involving the Mechatronics BS and MS.

   Currently, there are five MMET department faculty with full graduate school status to serve as the primary PhD advisors and there are three additional faculty that have associate graduate faculty status. It is anticipated that Applied Computing and other affiliated faculty can support PhD advising needs when appropriate. Other units in the College of Engineering have faculty that research advanced manufacturing methods and they are encouraged to request affiliated faculty appointments to assist with advising Manufacturing Engineering PhD students.

4. **Impact on Resources Required By other Units Within the University:**
   The Mathematics department has been contacted concerning the required MA5701 course and they are able to accommodate the influx of additional students at this time, but if the numbers increase it could cause difficulty for students to enroll in the future.

5. **Assessment of the ability to obtain the necessary resources assuming requested funds are obtained:**
   With the increase of automation and industry 4.0 in the US, there is not difficulty recruiting for faculty in this area.

6. **Past proposals. Has the department initiated any other new degree programs in the last five years:**
   The Manufacturing Engineering graduate certificate, proposal #71-21 and the Manufacturing Engineering MS, proposal #8-22. The enrollment is stated in item 2 which has met the prediction for enrollment in proposal #8-12 of 8 students in year one and 12 in year two.

7. **Departmental Budget contribution:**
   The total general fund budget is $1,315,806 for FY24. FY20 is the most recent report from Institutional Research for the tuition generated by the department, which is $1,602,343 by credit hours taught, and $3,441,090 for tuition generated by the number of credit hours taken by MMET enrolled students. It should be noted that in FY20 the Manufacturing Engineering graduate programs had not yet been implemented.

8. **How do the benefits from this program compare to other alternatives that are currently under consideration or development:**
   The College of Engineering is not considering any other PhD programs at this time.