



**REQUEST FOR AUTHORIZATION TO IMPLEMENT A MASTER
OF SCIENCE IN CONNECTED SYSTEMS ENGINEERING (CSE)
AT UNIVERSITY OF WISCONSIN-MILWAUKEE**
**PREPARED BY UW-MILWAUKEE, INDUSTRIAL AND MANUFACTURING
ENGINEERING DEPARTMENT**

ABSTRACT

The University of Wisconsin-Milwaukee proposes to establish a Master of Science in Connected Systems Engineering (M.S. CSE), to be offered by the Industrial and Manufacturing Engineering Department, in UWM's College of Engineering and Applied Sciences, in collaboration with UWM's Lubar College of Business and UWM's Connected Systems Institute (CSI). The development of this program responds to the need to prepare students for careers in connected systems in the manufacturing and service industries. According to indeed.com career guide (July 2023), systems engineering jobs promise 10% growth from 2021-2031. The 31-credit program is designed so that students will have a set of core courses that will present the fundamentals of connected systems, followed by a collection of technical electives, which are categorized to emphasize several focus areas. These areas include industrial engineering, manufacturing engineering, robotics and automation, cybersecurity and systems security, data analytics and enterprise resource planning and supply chain. The curriculum will involve the usage of case scenarios from the CSI automated manufacturing testbeds in most of the core courses. The need for this MS program is supported by the number of attendees in the non-credit re-skilling learning pathways offered through the CSI's Manufacturing Workforce Innovation Program (total of 189, between summer 2022-summer 2023). The skills learned in these pathways are embodied in the courses included in this new MS program. Feedback from local manufacturing industry leaders (see page 9-10) indicates that such an interdisciplinary MS program will prepare a pipeline of future industry leaders. Considering the recent faculty hires at the Industrial and Manufacturing department and the resources available at the Connected Systems Institute, no additional resources will be required for this program.

PROGRAM IDENTIFICATION

University Name

University of Wisconsin-Milwaukee

Title of Proposed Academic Degree Program

Master of Science Connected Systems Engineering

Degree Designation(s)

Master of Science

Suggested Classification of Instructional Program (CIP) Code

14.2701 – A program that prepares individuals to apply mathematical and scientific principles to the design, development, and operational evaluation of total systems solutions to a wide variety of engineering problems, including the integration of human, physical, energy, communications, management, and information requirements as needed, and the application of requisite analytical methods to specific situations.

Mode of Delivery: Single Institution, in-person delivery

The degree will be offered by the Industrial and Manufacturing Engineering department, with courses coming from the Lubar School of Business, Computer Science Department, School of Information Studies, and Mechanical Engineering. The degree will be based on flexible offerings. The courses are a majority in-person on-campus, with a possibility of some online.

Department or Functional Equivalent

Industrial and Manufacturing Engineering Department

College, School, or Functional Equivalent

College of Engineering and Applied Sciences

Proposed Date of Authorization

February 2024

Proposed Term of Implementation:

August 2024

PROGRAM INFORMATION

Program Overview

The proposed MS program in Connected Systems Engineering is a 31-credit Capstone-based program which will be offered by the Industrial and Manufacturing

Engineering Department in the College of Engineering and Applied Sciences, in collaboration with UWM's Connected Systems Institute (CSI) and the Lubar School of Business. This program, the first of its kind in the state of Wisconsin, is designed for graduates with at least a bachelor's degree in engineering and related fields, to reskill or upskill, and gain key knowledge that is necessary for current and future jobs in the manufacturing and service industries. The program entails courses in Industrial Internet of Things (IoT), data acquisition and data analytics, machine learning and artificial intelligence (AI), robotics/automation and digital twins as well as the sustainability in technological advances, taking ethical and social ramifications. Other courses include supply chain, enterprise resource planning and information technology. A unique aspect of this program is that the majority of the hands-on-experiential learning will take place in the state-of-the-art manufacturing testbeds and software that are available in the CSI.

Projected Enrollments and Graduates by Year Five

This graduate program is being established to attract students from Wisconsin, and mostly from the southeast Wisconsin region (current UWM students in our engineering and related bachelor's degree programs and potential students who are already working and have engineering or related backgrounds such as indicated in the eligibility requirements). According to UWM data, about 85% of UWM graduates start their careers in Wisconsin upon completion of their bachelor's degrees. We envision that this MS program will attract a wide range of graduates, with engineering and related backgrounds, who wish to reskill or upskill in response to the changing job opportunities. We also consider that the program will be attractive to international students. The graduate program will equip students with the knowledge necessary in the current Industry 4.0 era, such as systems engineering, robotics, artificial intelligence (AI) and machine learning, ethics regarding the use and development of technology and information.

Table 1 provides the enrollment and graduation projections, year 1 starting in Fall 2024, with a 3-semester completion for full-time students and 5 semester completion for part-time students. The program is flexible (students are not in cohorts), so students may take as few as 3-4 cr per semester, but for purposes of calculations we assume 10 cr per semester for full-time and 6 cr taken per semester for part-time students. This estimation does not include summer semesters. Because the current MS graduation rate (Industrial and Manufacturing Engineering) is about 95%, the Table has a built-in 90% retention rate, and we assume 75% of the students are expected to be full-time and the other 25% are part-time. At the end of the first five years, about 112 students will have enrolled and 67 students will have graduated. Note, Table 1 tracks enrollment by year rather than by semester. Details on the calculations are provided in the Budget Cost and Revenue Projections Narrative and Spreadsheet.

Table 1: Five-Year Enrollment and Completion Projections by Headcount

| Students/Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|----------------------|---------------|---------------|---------------|---------------|---------------|
| New Students | 15 | 18 | 22 | 26 | 31 |
| Continuing Students | - | 8 | 12 | 14 | 17 |

| | | | | | |
|---------------------|----|----|----|----|----|
| Total Enrollment | 15 | 26 | 34 | 40 | 48 |
| Graduating Students | - | 10 | 16 | 19 | 23 |

Tuition Structure

Tuition revenues were calculated based on the Fall 2023 UWM graduate tuition and fees schedule or students enrolled in the College of Engineering and Applied Sciences. In this proposal, we estimate that a full-time student will be taking 10 credit hours a semester, paying a total of \$6,132 in-state tuition, including \$782 in seg fees. The part-time students will be taking 6 credit hours a semester, paying a total of \$4,668 in-state per semester, including \$655 in seg fees. A conservative approach has been taken in estimating the cost projections, but we anticipate that a proportion of the students will be paying non-resident rates which are \$12,848 for full-time and \$9,704 for part-time students. A note here is that graduate tuition costs at UWM plateau at 8 credits.

Considering the multi-disciplinary selection of the courses from multiple academic departments, the mode of delivery is diverse; in-person or online. Therefore, in addition to the tuition and segregated fees, students who choose courses with online offerings will incur \$30 per credit for online courses. Also, some courses will be delivered by schools which charge 'master's surcharge fees. For instance, courses taken from the Lubar School of Business will carry an additional \$167.71 per credit. A note here is that these additional costs (online and master's surcharges) do not plateau at 8 credits.

Student Learning and Program Outcomes

The core objective of this MS in Connected Systems Engineering is to equip students to solve complex and critical system-level problems in the manufacturing and service industries. This overarching goal embodies the mission of the Institute of Industrial and Systems Engineers (IISE), the premier professional organization for systems engineers ("we serve those who solve the complex and critical problems of the world"). Specifically, students graduating from the MS in Connected Systems Engineering program will be able to:

- Understand, analyze, integrate, and validate complex systems.
- Apply and integrate the appropriate data analytical skills and tools to solve industry problems under uncertain conditions.
- Synthesize diverse business models and identify model features that ensure system agility.
- Design coherent industrial system-level solutions using Industry Internet of Things (IIOT) solutions including data analytics, remote sensing and controls, robotics and automation, mixed reality, digital twin and cybersecurity solutions.
- Synthesize, evaluate and apply measurable key performance indices to assess the effectiveness of the proposed system-level solutions.

Program Curriculum Requirements

The program is in tandem with the existing master's programs at CEAS (Table 2), in that it consists of 18 credits of required core courses, 3 credits of the capstone completion course, 1 credit of writing effectiveness and 9 credits of elective courses.

Table 2. The General UWM CEAS Non-thesis Capstone MS option credit requirements.

| Requirement Description | Credits |
|--|----------------|
| A minimum of 18 credits in an approved technical program | 18 |
| A minimum of 9 credits of approved electives | 9 |
| 1 credit of Effective Technical Writing Course | 1 |
| A minimum of 3 credits of a capstone project course (or independent study) | 3 |

The electives can be selected from a wide variety of courses from several programs in UWM, including Industrial and Manufacturing Engineering, Lubar School of Business, Computer Science, Mechanical Engineering, and the School of Information Studies. As shown in the curriculum (pages 4-6 of this document), the elective courses have been grouped by focus areas, so that a student can select all 9 elective credits from a single focus area if they wish to delve deeper into a focus area. Otherwise, students are free to take a mix of courses from multiple focus areas.

Table 2: Masters in Connected Systems Engineering Program Curriculum

Academic degree program or major course requirements:

| Core Courses | | 22 credits |
|---------------------|---|-------------------|
| IND ENG 741 | Foundational Technologies for Connected Systems | 1 credit |
| IND ENG 742 | Cloud Architecture for Connected Systems | 1 credit |
| BUS ADM 788 | Digital Supply Chain Management: Tracking and Tracing | 1 credit |
| IND ENG 540G | Foundations of Systems Engineering | 3 credits |
| IND ENG 555G | Manufacturing Systems Integration | 3 credits |
| IND ENG 715 | Data Acquisition and Visualization for Industrial Decision Making | 3 credits |
| IND ENG 716 | Engineering Statistical Analysis | 3 credits |
| Bus Adm 811 | Process and Workflow Management | 3 credits |
| IND ENG 999 | Advanced Independent study towards the capstone design-Capstone Project | 3 credits |
| EAS 701 | Effective Academic Writing | 1 credits |

Technical Elective Courses (See endnotes below the table)

9 credits

| Industrial Engineering Focus | | |
|-------------------------------------|--|-----------|
| Ind Eng 455G | Operations Research I | 3 credits |
| Ind Eng 465G | Operations Research II | 3 credits |
| Ind Eng 475G | Simulation Methodology | 3 credits |
| Ind Eng 550G | Control of Automated Manufacturing Systems | 3 credits |

| | | |
|--------------|---|-----------|
| Ind Eng 571G | Quality Control | 3 credits |
| Ind Eng 575G | Design of Experiments | 3 credits |
| Ind Eng 717 | Operations Research in Engineering Management | 3 credits |
| Ind Eng 765 | Operations Research Methods | 3 credits |
| Ind Eng 777 | Scheduling and Realtime Resource Management | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |

Manufacturing Engineering Focus:

| | | |
|--------------|---|-----------|
| Ind Eng 550G | Control of Automated Manufacturing Systems | 3 credits |
| Ind Eng 572G | Reliability Engineering | 3 credits |
| Ind Eng 587G | Lean Manufacturing | 3 credits |
| Ind Eng 751 | Flexible Manufacturing Systems | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |

Enterprise Resource Planning Focus:

| | | |
|--------------|---|-----------|
| Bus Mgmt 733 | Enterprise Simulation Game | 3 credits |
| Bus Adm 781 | Enabling Supply Chains with SAP | 3 credits |
| Bus Adm 816 | Business Intelligence Technologies and Solutions | 3 credits |
| Bus Adm 818 | Information Systems Practicum (*ERP project only) | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |

Digital Supply Chain Management Focus:

| | | |
|-------------|---|-----------|
| Ind Eng 590 | Global Supply Chains | |
| Bus Adm 781 | Enabling Supply Chains with SAP | 3 credits |
| Bus Adm 782 | Supply Chain Technology and Simulation | 3 credits |
| Bus Adm 783 | Modeling and Analytics in Supply Chain | 3 credits |
| Bus Adm 787 | Managing Connected Supply Chains | 3 credits |
| Bus Adm 789 | Service Operations Management | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |

Mechatronics/Robotics/Digital Twin Focus

| | | |
|---------------|---|-----------|
| Mech Eng 476G | Introduction to Robotics | 3 credits |
| Mech Eng 479G | Advanced Mechatronics | 3 credits |
| Mech Eng 733 | Sensors and Systems | 3 credits |
| Comp Sci 725 | Robot Motion Planning | 3 credits |
| Comp Sci 746 | Immersive Technologies and 3D User Interfaces | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |

AI/Machine Learning Focus

| | | |
|---------------|-----------------------------|-----------|
| Comp Sci 425G | Introduction to Data Mining | 3 credits |
| Comp Sci 710 | Artificial Intelligence | 3 credits |

| | | |
|----------------------------|---|-------------------|
| Comp Sci 711 | Machine Learning | 3 credits |
| Comp Sci 715 | Programming for Machine Learning | 3 credits |
| INFOST 582G | Introduction to Data Science | 3 credits |
| Cybersecurity Focus | | |
| Comp Sci 469G | Introduction to Computer Security | 3 credits |
| INFOST 583G | Survey of Information Security | 3 credits |
| INFOST 695G | Ethical Hacking I | 3 credits |
| INFOST 696G | Ethical Hacking II | 3 credits |
| INFOST 761 | Information Privacy | 3 credits |
| INFOST 784 | Information Security Management | 3 credits |
| Ind Eng 890 | Advanced Topics in Industrial and Systems Engineering | 3 credits |
| Total Credits | | 31 credits |

NOTE: Ind Eng 890: Advanced Topics in Industrial and Systems Engineering. Qualifying topics include Global Supply Chain and Sustainable Technologies: Social and Ethical will count.

Eligibility Requirements

Applicants must meet UWM's [Graduate School's mandated admissions requirements](#).

In addition:

1. Applicants should have a baccalaureate degree in engineering or related fields (mathematics, data science, statistics or a natural science) from an accredited college or university.
2. Applications will be reviewed by the Industrial and Manufacturing Engineering Department Faculty Committee to assess academic achievement and ability to do intensive graduate-level work.

Collaborative Nature of the Program

This Master of Science in Connected Systems Engineering (M.S. CSE) will be offered by the Industrial and Manufacturing Engineering Department, in UWM's College of Engineering and Applied Sciences. Internal collaborators represent departments/schools from which students will take some of the required courses or technical electives. They include UWM's Lubar College of Business, UWM's School of Information Studies, UWM's Department of Mechanical Engineering and UWM's Computer Science Department. In addition, UWM's Connected Systems Institute will provide access to the test-beds, software, personnel time and other resources that students will need for hands-on learning in the courses and capstone projects. External collaborators will include manufacturing and service industries that will provide case projects for the capstone course.

Projected Time to Degree:

The estimated time to degree is 3-semesters for full-time students and 5 semester completion for part-time students. This is within the expected timeline for a masters degree

in the College of Engineering and Applied Sciences. In addition, any student enrolled must graduate within 5 years of enrollment, or otherwise request for exemption through the UWM Graduate School.

Program Review and Accreditation

Consistent with all other graduate programs in CEAS, this proposed MS program will be accredited through the Higher Learning Commission (HLC). The HLC together with the internal UWM program review processes will provide the necessary program assessment and review oversight.

PROGRAM JUSTIFICATION

Rationale and Relation to UWM's Mission

The UW-Milwaukee Select Mission Statement, which can be found at <https://uwm.edu/mission/> states that:

"To fulfill its mission as a major urban doctoral university and to meet the diverse needs of Wisconsin's largest metropolitan area, the University of Wisconsin-Milwaukee must provide a wide array of degree programs [...]. Fulfilling this mission requires the pursuit of these mutually reinforcing academic goals:

- *To develop and maintain high quality undergraduate, graduate, and continuing education programs appropriate to a major urban doctoral university.*
- *To attract highly qualified students who demonstrate the potential for intellectual development, innovation, and leadership for their communities.*
- *To further academic and professional opportunities at all levels for women, minority, part-time, and financially or educationally disadvantaged students.*
- *To promote public service and research efforts directed toward meeting the social, economic, and cultural needs of the state of Wisconsin and its metropolitan areas.*
- *To provide educational leadership in meeting future social, cultural, and technological challenges."*

Among the goals listed in the UWM statement, the MS in Connected Systems Engineering program will also:

- Prepare and graduate a workforce that is ready to lead and contribute in industry amidst disruptions that are being brought about by a proliferation of technology, and other social-cultural changes.
- Provide academic and professional opportunities at all levels for students from diverse backgrounds.
- To establish and maintain productive relationships with companies locally, regionally, nationally, and internationally.

Though the larger society may be made to believe that AI and automation is "coming for their jobs", we believe that, to the contrary, AI and automation, which are among the disruptive technologies, are not only increasing productivity, but also resulting in new job opportunities. This MS program, which will be skilling a workforce for these new job opportunities, has received the endorsement of the Industrial and Manufacturing

Engineering program's Industry Advisory Board, as well as the CSI's academic and industry advisory boards. This new program will enable the current workforce to reskill for job opportunities in systems engineering, with specializations in automation, data analytics, artificial intelligence, digital supply chain and optimization of industry operation.

University Program Array

The College of engineering and Applied Sciences provide MS programs in: Civil Engineering/Urban Planning, Computer Science (regular and professional track); Biomedical Engineering; Energy Engineering; Electrical and Computer Engineering; Mechanical Engineering; Industrial Engineering; Manufacturing Engineering, Occupation and Biomechanics Engineering and Materials Engineering. This proposed MS program will increase the overall enrolment in CEAS graduate programs.

Other Related Programs in the University of Wisconsin-System

Currently there are no programs in the state of Wisconsin that are exactly like the proposed program. There are, however, the following MS programs that are related: UW-Madison offers MS in Sustainable Systems Engineering, MS in Industrial Engineering (Systems Engineering and Analytics), MS in Data Analytics, MS in Design + Innovation, MS in Engineering Management, UW-Platteville offers a general MS in Engineering. The Milwaukee School of Engineering offers an MS in Engineering Management. None of the curriculum in these related programs offer a combination of knowledge areas that our proposed MS program will cover, including: IoT, machine learning, connected systems, multi-echelon inventory optimization, blockchain, robotics, cyber-security, or real-time data analytics.

Need of Graduates as Indicated by Current Students

The IME department offered a topics course in connected systems (CS) at a U/G level, as a technical elective from Fall 2016 till Spring 2018 (about 20 students per semester). This course served as a precursor to the proposed MS program. The 3-credit CS course encompassed discussions, assignments, and projects in: (1) Emerging technologies that have enabled connectivity and digitization of manufacturing and service industries. (2) Connected systems network and network security, (3) cybersecurity, (4) data management and data flow in connected systems, (5) Predictive analytics and (6) Organizational models and culture. This course was well received by students, who asked for more courses of such flavor. We are currently offering Ind Eng 550, a course that provides skills in the automation of manufacturing systems. This later course has been a dealmaker for some graduates (about 20) in securing job positions. The need for this MS program is also supported by the number of attendees in the non-credit re-skilling learning pathways offered through the CSI's Manufacturing Workforce Innovation Program (total of 189, between summer 2022-summer 2023). The skills learned in these pathways are embodied in the courses included in this new MS program. We believe that given these pointers, and encouragement by our students, we will receive applicants to the MS program from students currently in our engineering B.S. programs, as well as local, regional, and international students. While we understand that in the short term, this new program may increase competition for other MS programs in the

IME department, but we believe that in the long run, this new program, which offers skills that are currently needed in the industry, will increase enrollment in the other existing MS programs, because the new courses in this new MS program will serve as technical electives for the existing MS programs.

Need of Graduates as Indicated by Market Demand

Rapid technological changes necessitate reskilling and upskilling of the current engineering workforce. According to the US Bureau of Labor Statistics' projections between 2022-2030, the number of jobs that require STEM- (Science, Technology, Engineering and Mathematics) related skills will grow faster than other employment ([Employment in STEM occupations : U.S. Bureau of Labor Statistics \(bls.gov\)](https://www.bls.gov/employment-in-stem-occupations)). There are job opportunities on the growth today, that were not in demand a decade ago. These include expert systems engineer, artificial intelligence engineer, cloud architecture engineer, data analyst, among others. Our MS program is geared toward our current students in the Bachelor's degrees and the local and regional workforce with engineering and related backgrounds who wish to gain more knowledge in systems engineering and choose from among the elective focus areas.

A Principal Engineer from Heartland Technology Group, Inc., an engineering employer in the region and industry partner at CSI stated that, "As a leading Wisconsin employer in industrial automation, an advanced degree in Industry Internet of Things (IIoT), as proposed by the UW Milwaukee College of Engineering and Applied Sciences, is vital to the growth of our economy. As more industries adopt IIoT technologies to improve efficiency, reduce costs, and transform their operations, the demand for professionals with IIoT skills will grow exponentially. Beyond manufacturing, IIoT is expected to create new jobs in areas like data analysis, system management, and cybersecurity."

Additionally, the Directors of Global Academic Engagement and Advanced Technologies at Rockwell Automation Inc. jointly support the establishment of the MS CSE as follows: "We believe that an interdisciplinary master's program focused on connected systems is a critical step to closing the current industry knowledge gap and preparing a pipeline of future industry leaders. Seeing this outcome was a core reason RA engaged in developing the Connected Systems Institute (CSI) and we fully support the MS program's establishment." Rockwell Automation is a leading employer of UWM's graduates and key industry partner to the UWM IME Department and UWM's CSI. CSI offers several workshops for workforce development, whose contents are embodied in the new MS in Connected Systems Engineering. According to UWM CSI data on attendees, (summer 2022-summer 2023) a total of 181 learners, all of whom are employees from local manufacturing industries, came through some of the non-credit learning pathways offered through the CSI Manufacturing Workforce Innovation Program.