

The University Senate of Michigan Technological University
Proposal 30-25

Proposal for a Graduate Certificate in Robust Embedded Software

<https://www.mtu.edu/senate/policies-procedures/list-policies/411.1/>

Basic Program Information

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Program/Degree type: Graduate Certificate

Program Title: Graduate Certificate in Robust Embedded Software

Planned Implementation Date: Fall 2026

Program location/modality: Online

Target student population: Working professionals in the embedded/cyber physical systems; Michigan Tech graduates in the following majors: Computer Science, Computer Engineering, Electrical Engineering and Mechanical Engineering.

General description and characteristics of program

This certificate includes three 3-credit courses that can be completed in 12 months. The courses are project-based where students will get hands-on experiences in the development of embedded software. Students can take at most two courses per semester due to prerequisite requirements and resource constraints. The target students are mainly online participants, but on-campus students can benefit from in-person access to the instructors in their office hours. Some of the contents of one of the courses is taken from CS4710, Model-Driven Software Development, but significant additional materials must be included to cover embedded software. The cost of delivery of this certificate is low, but there will be a start-up cost for course development. If enrollment grows over time, then we will expand the course offerings and will need more resources.

Rationale

Since the critical infrastructure of our society is monitored and controlled by computing devices embedded in larger systems (e.g., transportation systems, medical devices), the resilience and robustness of software that runs such embedded systems is of paramount importance. Due to high demand for embedded programmers, many graduates from disciplines other than Computer Science land in positions where they are expected to program embedded systems. We have a responsibility to train such professionals and equip them with the necessary skills for the development of high assurance embedded software.

In terms of job market potential, the projection of the U.S. Bureau of Labor Statistics (BLS) indicates that the overall employment of software engineers with expertise in robustness and

quality assurance expertise is expected to grow 25% from 2022 to 2032, which is much faster than the average for all occupations. The BLS reports that the median salary of embedded Software Engineers was about \$127K in 2022. [Lightcast](#) reports that in 2022, there were 1,578,965 jobs for embedded software engineers in the US and 31% growth is expected until 2032.

This certificate provides an opportunity for Michigan Tech's engineering graduates as well as professionals who work in embedded systems industries (e.g., automotive, medical devices, etc.) in Michigan, its neighboring States and beyond to improve their software engineering and software quality assurance skills in a short period of time with the flexibility of working remotely.

Related programs: within Michigan Tech and at other institutions

The only courses related to embedded software at Michigan Tech include EE3171, Microcontroller Applications, and EE3173, Hardware/Software System Integration, which are mainly geared towards Electrical and Computer Engineering students, with little focus on software robustness or Software Engineering aspects of embedded programs. We have discussed the idea of this certificate with the instructor of these courses and he has agreed to teach one or two modules of one of the courses of this certificate. To the best of our knowledge, certificates and degrees on embedded software are scarce across the nation, despite the pressing need for embedded software workforce in the next decade (as stated in the rationale of this proposal). We have found a similar certificate presented by the [University of Washington](#). Moreover, [Lawrence Technological University](#) in Michigan offers an undergraduate degree for educating experts in Embedded Software, which further indicates the significance of this program for Michigan industries. There will be a dire need for embedded software workforce in the next decade (as stated in the rationale of this proposal), and we believe that Michigan Tech can play an important role in the training of such workforce in Michigan and beyond. Overall, a certificate in developing Robust Embedded Software (RES) is highly needed on-campus, in Michigan and across the nation.

Projected Enrollment

Projecting an accurate enrollment is difficult, but given the current vacuum on-campus and in the State of Michigan, we anticipate that in the first year, we will have around 10 students. There is a great potential to recruit students from neighboring states of Wisconsin and Minnesota, given their strong industrial prowess in the field of medical devices and avionics. We predict that the automotive industry in Michigan will also be interested in training their professional workforce through this certificate. Initially, we can accommodate 10 online students without additional teaching resources, but as the enrollment grows there will be a need for additional instructional resources. We would like to note that due to the hands-on nature of this certificate where students will work on design, verification, implementation and testing of embedded software, instructors will have to spend more than average time on course development and teaching.

Specialized Accreditation Requirements

There is no discipline-specific accreditation.

Professional Licensure Requirements

No licensure is required.

Curriculum Details

Students should successfully pass the following 3-credit courses:

- CS4xxx: Foundations of Embedded Software (FES)
- CS5xxx: Model-Driven Development and Verification of Embedded Software (MDDVES)
- CS5xxx: Testing and Quality Assurance of Embedded Software (TQAES)

Learning Goals

After taking this certificate, students will be able to *design, verify and test event-driven and concurrent embedded software in the context of a team using state-of-the-art methods and tools.*

Assessment Plan

We will annually assess the Graduate Learning Outcome (GLO) using the following assessment points:

Assessment Points for GLO	GLO addressed	Notes
Mastery of design, verification and testing knowledge and skills in individual assignments and projects	GLO	At most one 'AB' and the rest "A's" as excellent, At most one 'B' and no grade lower than 'B' as satisfactory, No grade higher than 'B' as marginal, All grades below 'B' as deficient.
Teamwork and communication skills in group projects.	GLO	Through peer evaluation forms, students evaluate the contributions of their teammate(s) as 'satisfactory', 'marginal' or 'unsatisfactory'. Instructors take this feedback into consideration for the final grade of each individual in the related course.

Curriculum Design

New Course Descriptions

There will be three new 3-credit courses that will be offered in a project-based fashion where the knowledge and skills acquired in this program are put into action. The course proposals are attached to this program proposal. Students will experience all stages of developing robust embedded software in the context of course projects, including design of functional and non-functional properties, design verification, implementation and testing. The title and descriptions of these courses are as follows:

- *Foundations of Embedded Software (FES)*¹:
 - Provides an introduction to the architecture of microcontrollers, the embedded software stack (starting from firmware, hardware abstraction layer, real-time operating systems, device drivers and APIs), programming methods for embedded systems, and tool chains for programming and debugging of embedded software.
- *Model-Driven Development and Verification of Embedded Software (MDDVES)*:
 - Focuses on the use of methods and tools in the design, verification and validation (V&V) of hybrid computing software, where discrete computing meets the continuous physical world. Topics include hybrid programs and their requirements, modeling and simulation of embedded systems, timed temporal logic, model checking of timed properties, and use of model checkers such as UPPAAL, Romeo, BIP, DREAM and the IF toolset.
- *Testing and Quality Assurance of Embedded Software (TQAES)*:
 - Concentrates on topics such as testing of functional and non-functional concerns, test harness development, test automation, performance testing (e.g., worst case execution time), testing real-time properties and testing in the presence of faults. The main focus of this course will be on methods and tools for implementation testing, but requirements and design testing will also be discussed. Examples of such methods include hardware-in-the-loop testing, code coverage analysis, worst case execution time analysis, scheduling analysis and trace analysis.

Timeline of Course Development and Offering:

The three courses will be developed and offered in the following sequence:

- Fall 2026: Foundations of Embedded Software
- Spring 2027: Model-Driven Development and Verification of Embedded Software
- Fall 2027: Testing and Quality Assurance of Embedded Software

We will make sure that these courses will undergo the on-line course review process after they are developed and taught the first time.

¹ This course is in general useful for CS and SE students. In particular, the following undergraduate courses can benefit from FES: Operating Systems (CS4411), Computer Security (CS4471), Trusted Software (CS4740), and Software Architecture (CS4740).

Prerequisites: Ideally, we would like the students to take these courses in sequence, but FES and MDDVES can be taken concurrently, while TQAES must be the last course.

Model Schedule

We propose the following schedules for the online offering of this certificate. The courses of this certificate are offered in a semester-long term. Summer enrollments will depend upon the availability and interest of students and the instructors. The program will start in Fall 2026 and the sequencing of the course offering is as follows:

Fall Start Schedule		
Fall	Spring	Summer or Fall
Foundations of Embedded Software (online)	Model-Driven Development and Verification of Embedded Software (online)	Testing and Quality Assurance of Embedded Software (online)

Faculty Qualifications

Ali Ebnenasir is the faculty member in charge of the design and development of this certificate. Christopher Cischke from the Computer Engineering Department in the College of Engineering will help in teaching at least some modules of the FES course. Dr. Ebnenasir's research expertise focuses on robustness and dependability aspects of software systems, and he has designed CS4710 and has offered and improved it regularly in the past 12 years. Moreover, Dr. Wallace will participate in the development of the courses. His expertise span over Testing, Requirements Elicitation and Formal Methods.

- Ali Ebnenasir <https://pages.mtu.edu/~aebnenas/>
- Charles Wallace <https://pages.mtu.edu/~wallace/>
- Christopher Cischke <https://pages.mtu.edu/~cmcischk/>

All faculty members meet Michigan Tech's qualification standards for online/remote instruction.

Program-specific policies, regulations, and rules

There are no program-specific policies or rules.

Resources Needed

Library and other learning resources needed

- Instructional needs: This program can be managed initially with no additional instructional resources; however, as mentioned before, when the program grows beyond 10 students, there may be a need for additional instructional resources. Moreover, the development of new courses may require some sort of compensation.
- Hardware: In the first few years of this program, we will use simulators of embedded platforms/processors for actual programming and testing. As enrollment grows, this certificate program will need some embedded systems kits for students so they can experiment on the actual hardware platforms too. We will also use a few Arduino microcomputer boards that Dr. Ebnenasir procured for an IoT course that he designed and offered in Spring 2020, which can be used for some modules of this certificate, but not all. The cost of each embedded systems kit may vary between \$300 to \$800, depending on the brand and peripheral equipment. One source of funding for such costs will be a lab fee that we will include for related courses of this certificate.

Suitability of existing space, facilities, and equipment

Existing space, facilities and equipment are sufficient.

Program Costs (including development, marketing and maintenance)

The College of Computing may compensate the involved faculty members to develop the online courses. Using existing resources, the offering of the new courses of this certificate (after their development) can be done in an online fashion as long as online enrollment does not exceed 10 students per course. College of Computing marketing will help with the marketing of this program.