Submit a PDF copy of this completed Project Description Template to ucite@case.edu. The information in your project description should address the requested points, clarify your intentions, and concisely convey your goals.

The review committee will read applications as anonymous submissions. Please do not put your name anywhere in the text of your project description. You may include other details, such as your department and course titles.

Project Title: Enabling Dual-Delivery of Hardware-based Laboratory Courses

I. Project Nature & Goals

Address the following questions as you describe the nature and goals of your project

How will your project produce better teaching and deeper student learning? What scholarship about teaching and learning does your project engage with? What service learning opportunities may be possible through your project? How might your project align with the THINK BIG strategic plan or departmental goals?

The rapid switch to remote learning as a result of the COVID-19 pandemic has caused a significant disruption in delivering academic programs for our students. The impact of this switch varies considerably by course, curriculum, and educational program. For example, highly technical courses are impacted differently than discussion-based courses, and laboratory-oriented courses are impacted differently than lecture-only courses. Some of the learning outcomes for laboratory-oriented courses in the engineering and science curriculums can be achieved with remote learning with minimal translation (e.g., data analysis), and simulation can also play an important role in some instances. Other learning outcomes, however, can only be achieved with hands-on experience with specialized equipment and instrumentation and experiments and in many instances there are no substitutes.

We developed and delivered a pilot offering of a new engineering course, EECS397 – Design of IoT Edge Devices, in Spring semester 2020, in the Department of Electrical, Computer, and Systems Engineering (ECSE). The course is designed to educate students on designing products for the new computing paradigm known as Edge Computing. Edge Computing that is proving to be a critical technology in the evolution of the Internet of Things (IoT), allowing data computations and analytics to occur close to where the data is acquired instead of transmitting large volumes of data to the cloud. This course was developed with the generous support of the Intel Corporation that provided funds to support a graduate student and develop a new laboratory that includes custom Edge Computing development hardware (donated by Intel) that is central to the delivery of the integrated lecture and laboratory curriculum of the course.

In Spring semester 2020, the students barely had an opportunity to effectively use the laboratory before the university switched to remote learning. Many of the planned laboratory assignments had to be dropped because there was no feasible way for students to accomplish the learning goals without physical access to the electronic hardware in the laboratory.

We will be offering the Designing IoT Edge Devices course in Fall semester 2020 to a larger group of students after the initial pilot offering in Spring 2020. The university's directive to support dual-delivery, however, creates challenges for laboratory-based courses like this. The goal of this proposed Nord Grant is to develop procedures and technologies to support dual-delivery of hardware-based laboratory courses, using the Designing IoT Edge Devices course as an exemplar and test bed. The project is aligned with the Think Big initiative in developing novel educational approaches to enhance learning and experiences (Pathway 1) and innovative applications of technology that keep the learning of the student at the center (Pathway 2).

The updated, dual-delivery capable course, will use an integrated workflow based on software emulation of hardware, followed up by real-world hardware testing. Software for the development hardware can be built and tested in an emulated environment, and then subsequently deployed and tested on the actual hardware, remotely. This workflow parallels that used by many distributed development teams where hardware and software components are designed in different parts of the world; in addition, this working model provides an opportunity for remote laboratory experimentation while at the same time provides the students with a real-world introduction to a common, team-based industry design process.

The proposed work would start in Summer 2020 and continue through the delivery of the Design of IoT Edge Devices course in Fall 2020 and includes:

- Develop processes with [U]Tech for remote student VPN access to the workstations in the laboratory
- Develop processes and technology that will allow students to remotely build and "flash" custom software to the development hardware (typically requires direct manipulation of the hardware)
- Develop an apparatus to generate a physical, real-world stimulus to sensors connected to the development hardware, under remote student control (leveraging Sears Think[box] fabrication capabilities)
- Develop additional software-emulation labs to augment the hardware labs
- Rework syllabus and courseware to integrate the emulation-to-hardware workflow
- Augment each of the 15 workstations with suitable remote technologies to support rich remote learning experiences:
    - Network controlled power strips to allow students to remotely cycle power on development hardware, when necessary to reset the system
    - Privacy-preserving webcams to only observe the operation of the custom edge computing development hardware
    - Custom-designed remote sensor stimulus apparatus that will allow remote students to generate physical, real-world stimulus to sensors connected to the development hardware
    - Transfer of real-time data for visualization, analysis and interpretation during the remote experiments
    - Implemented safety features on the custom hardware for unattended operation

II. Professional Impact

What is the relationship between your project and your teaching and/or research responsibilities at CWRU? Will your project have short-term or long-term impact on teaching and learning? How do you plan to maximize the number of students that may benefit from involvement in this project?

I am an experienced educator with teaching and research interests that align in the areas of signals, systems, data analytics and controls. My recent research has been focused on the emerging area of the Internet of Things (IoT) that represents a significant opportunity for innovation in the public sector (Smart and Sensible City applications) and the private sector (Smart Manufacturing and Connected Health). IoT refers specifically to the use of sensors, systems and data to solve some of the most challenging problems facing society such as safety, mobility, energy, and the efficient use of natural resources. Although technology is the key enabler, our approach to IoT is problem driven keeping human at the center (aligned with Pathway 2). Experiential learning activities are critical to the development of IoT technologies, and hands on hardware laboratories are key! Developing robust and resilient educational delivery strategies to provide these experiences to all students is challenging as we experienced in the last several months of Spring semester 2020.

Dual-delivery of the Design of IoT Edge Devices course (Fall 2020) provides an opportunity for remote students to experience the lab and also creates a natural opportunity to incorporate additional uses of software emulation in the course, which is becoming increasingly important in industry as it allows faster development cycles and reduces reliance on limited prototype hardware. We will modify the course to alternate between assignments that are implemented in full software emulation, where students solve the lab assignment completely on a computer that emulates the development hardware CPU and sensors, and assignments where the students then deploy the solution from the emulation on the physical hardware and validate the solution in real-world conditions. This iterative process between emulation and hardware will provide a unique opportunity for remote studies to effectively engage in the hardware laboratory experience and will allow all students (on campus and remote) to experience industry-accepted approaches for hardware and software development projects. We expect that the approach developed to remote hardware lab experiences developed in this project will be incorporated into the Design of IoT Edge Devices course for future offerings and will also provide a foundation for many other courses in the future, thus maximizing the benefits of our work. Further, this project will:

- Develop a case study for the delivering of remote, electronics-based courses
- Present a Seminar/Workshop for CSE in after the Fall 2020 semster on Lessons Learned for long-term impact
- Prepare an ASEE Paper submission to discuss the approach, experience, and lessons-learned

III. Evidence of Project Goals & Student Learning

What evidence will you seek to collect and analyze to determine how well or to what extent project goals were achieved? How will you measure evidence of student learning and/or teacher change?

Because of the dual-delivery offering of the Design of IoT Edge Devices course, we will have a unique opportunity to evaluate the effectiveness of our proposed approach on learning and comprehension of key concepts, techniques and methods. The two student cohorts (remote and on-campus) will have the same lectures and lab assignments, but will be experiencing the hardware aspects of the course in very different ways! Further, the novel Fall 2020 Academic calendar that is being considered will provide another experimental opportunity to judge the effectiveness of the remote delivery of the course; some students will be remote for the entire semester, some studies will be on campus and using the hardware lab, but ALL students will be remote for the last several weeks of the course. This will allow us to compare the mastery of the remote and on campus students up to the Thanksgiving Holiday break, and then also observe what happens when on-campus students transition to remote learning at the end of the semester as compared to those that have been remote all semester. Because of the small sample size, we will not be able to make any statistically meaningful inferences from the data, but it should provide guidance on future developments of remote laboratory instruction.

We will use lab assignments (working demonstrations, brief reports), online quizzes in Canvas, and a final project (working demonstration, presentation, brief report) as well as student surveys to evaluate students and project goals. Data from the course will also be used to support ABET accreditation student outcome criteria (1 and 6, respectively): an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics, and an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

IVa. Budget Narrative & Timeline

How will Nord Grant funds be used to support the project – for materials/equipment, for student stipends, or for something else? What support, if any, will the project receive from other sources, including on-campus (e.g. department funds) or beyond-campus (e.g. discipline-specific awards) funds? What is the proposed timeline for the project? Is this a new project or is the work already underway?

The project will run during Summer and Fall 2020.

Planning and initial execution will occur during Summer 2020.

The offering of the Design of IoT Edge Devices course in Fall 2020 will be used to evaluate the procedures and technologies developed during the Summer.

Funds will be spent on remote-enabling equipment to be effectively used by remote students, this will require developing 15 workstations that each include: smart switch-$100, webcam-$100, fabrication-$50, remote sensor

stimulus apparatus-$200; for a total cost of $450 per workstation.

Matching funds from the ECSE department will support a graduate student for the Summer and Fall to work on the project.

IVb. Budget Details	
Expenses (*round to the nearest dollar amount*). SEE NOTES BELOW	
Equipment to Enable Remote Operation of Each Workstation (15 @ $450/each)	$6,750
Total Nord Grant Expenses	**$6,750**
Cost Sharing	
Graduate Student ($15 hour; 20 hours/week; 22 weeks)	$6,600
Total Cost Sharing	**$6,600**
TOTAL PROJECT COST	**$13,350**