February 9, 2017

MEMORANDUM

TO: Darryll Pines  
Dean, A. James Clark School of Engineering

FROM: Elizabeth Beise  
Associate Provost for Academic Planning and Programs

SUBJECT: Proposal to Establish an Additive Manufacturing Option for the Post-Baccalaureate Certificate of Engineering (PCC Log No. 16030)

At its meeting on February 3, 2017, the Senate Committee on Programs, Curricula and Courses approved the proposal to establish an Additive Manufacturing Option for the Post-Baccalaureate Certificate of Engineering. A copy of the proposal is attached.

This new option is effective Fall 2017. Please ensure that the option is fully described in the Graduate Catalog and in all relevant descriptive materials.

MDC/  
Enclosure

cc: Andrew Harris, Chair, Senate PCC Committee  
Barbara Gill, Office of Enrollment Management  
Reka Montfort, University Senate  
Chip Denman, Division of Information Technology  
Pam Phillips, Institutional Research, Planning & Assessment  
Anne Turkos, University Archives  
Linda Yokoi, Office of the Registrar  
Alex Chen, Graduate School  
William Fourney, A. James Clark School of Engineering  
George Syrmos, Office of Advanced Engineering Education
THE UNIVERSITY OF MARYLAND, COLLEGE PARK
PROGRAM/CURRICULUM/UNIT PROPOSAL

• Please email the rest of the proposal as an MSWord attachment to pcc-submissions@umd.edu.

• Please submit the signed form to the Office of the Associate Provost for Academic Planning and Programs, 1119 Main Administration Building, Campus.

College/School: ENGR
Please also add College/School Unit Code-First 8 digits:
Unit Codes can be found at: https://hvpprod.umd.edu/Html_Reports/a

Department/Program: Office of Advanced Engineering Education
Please also add Department/Program Unit Code-Last 7 digits:

Type of Action (choose one):
☐ Curriculum change (including informal specializations) ☐ New academic degree/award program
☐ Curriculum change for an LEP Program ☐ New Professional Studies award iteration
☐ Renaming of program or formal Area of Concentration ☐ New Minor
☐ Addition/deletion of formal Area of Concentration ☐ Other
☐ Suspend/delete program

Italics indicate that the proposed program action must be presented to the full University Senate for consideration.

Summary of Proposed Action:
Creation of an academic option in Additive Manufacturing to the existing Graduate Certificate in Engineering Program (as Z###) through the Office of Advanced Engineering Education.

Departmental/Unit Contact Person for Proposal: George Syrmos

APPROVAL SIGNATURES - Please print name, sign, and date. Use additional lines for multi-unit programs.

1. Department Committee Chair: Hugh Bruck 10/14/16
2. Department Chair: George Syrmos 10/18/16
3. College/School PCC Chair: 11/4/16
4. Dean: Peter Kolmas 11/4/16
5. Dean of the Graduate School (if required): Jeffrey Frank 12/12/2016
6. Chair, Senate PCC: Andrew Harris 2/3/17
7. University Senate Chair (if required): Elizabeth Beiss 2/9/2017
8. Senior Vice President and Provost:
Proposal for a New Specialization in Additive Manufacturing in the Graduate Certificate in Engineering Program

I. Overview and Rationale

Established in 1994, the Office of Advanced Engineering Education (OAEE) in the Clark School of Engineering is responsible for lifelong learning programs designed for working engineers and technical professionals. OAEE offers both credit and non-credit programs, but our primary offerings are the Master of Engineering degree and the Post-Baccalaureate Graduate Certificate in Engineering degree. We refer to these degree programs as the Professional Master of Engineering (ENPM) Program and the Graduate Certificate in Engineering (GCEN) Program. The Master of Engineering degree is awarded with completion of ten courses (30 credits) and no thesis/research project, scholarly paper, or comprehensive exam are required. Each academic option has its own set of course requirements. The GCEN Program was developed to serve as a more highly focused area of study. It requires the completion of four specific courses (12 credits) by academic option. There are currently over 650 students in our programs with over 2500 graduates. Students take classes on campus, at regional education centers throughout Maryland, and seven programs are offered online. Enrollments have been averaging 53% on campus and 47% distance/online for the past few years.

OAEE currently offers twenty-two academic options under these two programs (http://advancedengineering.umd.edu/degrees-certificates). Academic options were originally versions of the Master of Science programs in each academic department (i.e. Aerospace, Mechanical, Electrical, etc.). However, as the need grew for more interdisciplinary programs, we began working with research institutes and centers in the Clark School to develop and offer programs to meet the needs of the engineering/technology community. We have developed niche academic options in Sustainable Energy, Project Management, Robotics, Energetic Concepts, Software, Reliability, Fire Protection, Regulatory Science, Cybersecurity, Energy Systems Management and Policy, Electronic Packaging and Transportation Systems. In 2003, we began offering many of our programs online to give national and worldwide access to the outstanding programs available at Maryland.

We propose the creation of an Additive Manufacturing academic option in the Graduate Certificate in Engineering Program that will be fully on-campus or via video-teleconferencing at remote sites and will be a complement to the options we currently offer and the research work being done in the Department of Mechanical Engineering and the Department of Bioengineering. Additive Manufacturing is an area that is revolutionizing design and manufacturing, as well as an area in which the A. James Clark School of Engineering at UMD has strong resources and expertise. As such, we are poised to offer a strong new program in this niche area to a wide audience looking to learn more about this area of the industry. As such, we are poised to offer a strong new program in this niche area to a wide audience looking to learn more about this area of the industry. The School currently houses a Makerbot Innovation Center that is available to everyone on campus for primarily FDM fabrication. We also have a research facility with a number of advanced Additive Manufacturing capabilities. It is also a core capability in many centers in the School, such as the Maryland Robotics Center, Maryland Nanocenter, and the University of Maryland Energy Research Center.

II. Program Audience

The primary target audience are engineers in local industries, including a number of government contractors. Additive Manufacturing has become a staple of all engineering facilities. However, their engineers receive very little formal training in designing structures and fabricating them with available production systems. Therefore, we envision a number of students will also pursue certificates given the pervasiveness of Additive Manufacturing in industry. We also envision expanding this degree program online in the future so that other domestic and international students can pursue and benefit from the program. Many of the students pursuing certificates may be enrolled or interested in advancing their education in other M.Eng. programs, including Sustainable Energy Engineering, Mechanical Engineering, Reliability Engineering, Electrical Engineering, Robotics, and Energetic Concepts. The 3D printing process, a core Additive Manufacturing technology, is growing at a compound annual rate of 23 percent from 2013 to 2020, reaching $8.4 billion (see http://www.3ders.org/articles/20131111-3d-printing-market-worth-billion-by-2020.html).
Full admission as a degree seeking student requires the following:

- A bachelor's degree, with a GPA of 3.0 or better, in engineering or science from an accredited institution.

III. Program Administration

OAEE provides administrative oversight to all academic options in the GCEN Program, including student services, faculty support, proctoring, admissions, and academic outreach. In addition, OAEE works with faculty to develop new courses and programs that meet the needs of the engineering/technology communities. OAEE researches industry needs, meets with private and public sector leaders, attends various professional society and technology conferences to learn about possible program development areas. For each academic option there is an identified academic advisor/content matter expert who advises OAEE and our students on curriculum matters. For the traditional academic options (i.e. aerospace, bioengineering, mechanical, etc.) an advisor is assigned by that department Chair. For our interdisciplinary programs, the Chair/Director of the primary department/research center/institute assigns an academic advisor. These interdisciplinary areas also have curriculum committees that review student and faculty performance, course content, and curriculum development. As with all programs in OAEE, curriculum and academic oversight for the core and elective courses will be through a faculty advisory committee that will collaborate with the OAEE Executive Director, making sure that both commitment to support this new specialization and academic excellence are in place. Evaluation and assessment of this option will be performed by the faculty of Mechanical Engineering, more specifically a faculty member in the Mechanical Engineering department will be the first academic advisor.

Professor Hugh Bruck will be the first academic advisor and will work with the OAEE Executive Director to ensure that academic integrity is met (see the attached Assessment Plan approved for all OAEE academic options). Professor Bruck also serves as the academic advisor for two other GCEN areas (Mechanical Engineering and Sustainable Energy Engineering) and is very familiar with our audience and programs. Lastly, the new specialization will comply with all UMCP policies and requirements for graduate admission, time of study, and graduation requirements.

IV. Curriculum

The curriculum identified represents the beginning of what will be an evolving program that will continue to offer the latest developments in this rapidly changing and critically important field of study.

Students in the Graduate Certificate in Engineering in Additive Manufacturing Program will complete 4 courses or 12 credits. Students will take 4 courses (out of 7 course options listed).

V. Budget Resources

The Office of Advanced Engineering Education is a self-support unit and the Graduate Certificate in Engineering Programs are administered through its resources.

VI. Graduate Certificate in Engineering Courses

Some courses listed below are already in existence within ENPM or ENME. Other courses, as indicated, will be developed specifically to enhance this degree program.

- **Courses (Students Choose 4)**
  - **ENME 600 Engineering Design Methods (3 credits, offered each Fall)**
    - Prerequisites: Graduate standing or permission of instructor.
    - This is an introductory graduate level course in critical thinking about formal methods for design in mechanical engineering. Course participants gain background in these methods and the creative potential each offers to designers. Participants will formulate, present, and discuss their own opinions on the value and appropriate use of design materials for mechanical engineering.
  - **ENME 607/ENRE 671 Engineering Decision Making (3 credits, offered each Spring)**
- Also offered as: ENRE 671. Credit only granted for: ENME 808X, ENRE 671 or ENME 607. Formerly: ENME 808X.
- In the course of engineering design, project management, and other functions, engineers have to make decisions, almost always under time and budget constraints. Managing risk requires making decisions in the presence of uncertainty. This course will cover material on individual decision making, group decision making, and organizations of decision-makers. The course will present techniques for making better decisions, for understanding how decisions are related to each other, and for managing risk.
  - **ENME 610 Engineering Optimization (3 credits, offered each Fall)**
    - Prerequisite: Graduate standing or permission of instructor.
    - Also offered: “Credit only granted for ENME610 or ENPM808?” will be added through VPAC once we establish a course code for the new ENPM “Applied Engineering Optimization”
    - Overview of applied single- and multi-objective optimization and decision making concepts and techniques with applications in engineering design and/or manufacturing problems. Topics include formulation examples, concepts, optimality conditions, unconstrained/constrained methods, and post-optimality sensitivity analysis. Students are expected to work on a semester-long real-world multi-objective engineering project.
  - **ENME 744 Additive Manufacturing (3 credits, offered once per year)**
    - Prerequisite: ENME272 and ENME331; or students who have taken courses with comparable content may contact the department. Also offered as: ENME416. Credit only granted for: ENME 416 OR ENME 744.
    - Develop a comprehensive understanding of fundamental additive manufacturing-alternatively, "three-dimensional (3D) printing-approaches, including extrusion-based deposition, stereolithography, powder bed-based melting, and inkjet-based deposition. Cultivate a "design-for-additive manufacturing" skill set for combining computer-aided design (CAD) and computer-aided manufacturing (CAM) methodologies to produce successful 3D prints. Fabricate 3D mechanical objects using a variety of 3D printing technologies on campus. Execute a design project that demonstrates how additive manufacturing technologies can overcome critical limitations of traditional manufacturing processes.
  - **ENME 808E Applied Machine Learning for Engineering and Design (3 credits, offered once per year)**
    - Machine learning is a rapidly growing field at the intersection of computer science and statistics that is concerned with finding patterns in data. It is responsible for tremendous advances in technology, from personalized product recommendations to speech recognition in cell phones. The goal of this course is to provide a broad introduction to the key ideas in machine learning. The emphasis will be on intuition and practical examples rather than theoretical results, though some experience with probability, statistics, and linear algebra will be important. Through a variety of lecture examples and programming projects, students will learn how to apply powerful machine learning techniques to new problems, run evaluations and interpret results, and think about scaling up from thousands of data points to billions.
  - **ENPM 671 Advanced Mechanics of Materials (3 credits, offered each Spring)**
    - Formulate and quantitatively state the mechanical/physical responses of structural components and configurations subjected to loads, temperature, pre-strains etc. The two methods of analysis employed are the mechanics of materials approach and the theory of elasticity approach. Analysis and design of components of structural/machine systems as experienced in aeronautical, civil, mechanical and nuclear engineering.
  - **ENPM 808? Applied Engineering Optimization (3 credits, offered each Spring) In Development**
    - Credit only granted for ENME610 or ENPM808?
    - In Development – this course will cover various areas of Engineering Optimization, including some topology and software application topics, in an applied fashion. We aim for the initial offering of this course in Spring 2018.
**Graduate Certificate in Engineering (GCEN)**

For Time Period: Academic Year

Program Contact: Dr. George Syrmos

Phone: 301-405-3633

E-mail: syrmos@umd.edu

Date submitted to Academic Unit Head: ______________________

<table>
<thead>
<tr>
<th>Student Learning Outcomes for assessments that will occur during the academic year</th>
<th>Assessment Methods &amp; Criteria</th>
<th>Assessment Results</th>
<th>Impact of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demonstrate knowledge of advanced principles in engineering.</td>
<td><strong>Criterion:</strong> All ENPM courses offered during any given semester. The final exam in all these courses will include a question specifically tailored to demonstrate understanding of a fundamental principle in engineering. <strong>Measure:</strong> At least 70% of the students in every ENPM course offered during any given semester would be expected to successfully answer this question posed on the final exam.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Demonstrate knowledge of advanced principles in engineering.</td>
<td><strong>Criterion:</strong> 90% of the Graduate Certificate in Engineering students should have a GPA equal or greater than 3.0 <strong>Measure:</strong> GPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Demonstrate continued retention of students and progress towards degree completion.</td>
<td><strong>Criterion:</strong> 80% enrollment by existing students each semester.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10/23/2013
<table>
<thead>
<tr>
<th>Measure: Registrar's Enrollment Records.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4. Demonstrate completion of degree program.</strong></td>
</tr>
<tr>
<td>Criterion: 80% graduation rate of students within the five year limit for Graduate Certificate in Engineering students.</td>
</tr>
<tr>
<td>Measure: Registrar's Graduation Records.</td>
</tr>
<tr>
<td><strong>5. Point-of-graduation survey.</strong> The survey is web based. Graduating students, prior to the end of the semester, are sent the web site in which to fill in the appropriate information and submit the survey electronically. The survey seeks to ascertain a student's experiences in the GCEN Program regarding the quality of courses, the general program, faculty, and staff. The survey also collects information on employment (position, salary, etc.) at graduation.</td>
</tr>
<tr>
<td>Criterion: 50% response rate by graduating students.</td>
</tr>
<tr>
<td>Measure: Graduation Survey.</td>
</tr>
</tbody>
</table>
Additive Manufacturing Definition:

Additive Manufacturing is a new class of manufacturing processes with associated design principles that are being used extensively by engineers for prototyping concepts and to realize new products. It is the official industry standard term (ASTM F2792) for all applications of the technology. It is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.

Learning Outcomes:

Master of Engineering and Graduate Certificate in Engineering Level
OAEE manages two graduate programs – the Professional Master of Engineering (ENPM) and the Graduate Certificate in Engineering (GCEN) and within each program are many academic options with separate program codes. At the graduate level, the University of Maryland, and in turn our programs, are held to the Middle States Accreditation standards. In order to continue maintaining that accreditation, we have Graduate School-approved Assessment Methods, Criteria, and Results that we track and report in a graduate outcomes assessment on a regular basis. This data is reported to the Graduate School as a conglomeration of all academic option program codes within the ENPM and GCEN programs, respectively. Some of the program assessment criteria demonstrate more general outcomes surrounding overall knowledge of advanced principles in engineering based on things like retention in the program and cumulative GPA. However, other program assessment areas more specifically address learning outcomes in particular topic areas. For instance, each semester instructors of ENPM courses are asked to include a question on their final project or examination that requires each individual student to demonstrate an understanding of a fundamental principle in engineering relevant to each course topic area. The Office of Advanced Engineering Education then compiles and tracks this data by course. When reported to the Graduate School, and in turn Middle States, we provide one data point on the percentage of students able to demonstrate an understanding of a fundamental principle in engineering for the overall ENPM and GCEN programs, respectively. However, because this data is actually tracked and compiled on a semester basis by course, within our office we are also able to see trends in student learning outcome success in specific courses, as well as within blocks of courses associated with a particular academic option within one of our programs. (Assessment Methods, Criteria & Results sheets included in original proposal)

Additive Manufacturing Academic Option Level
The curriculum has more manufacturing, materials, and design content than a standard degree in Mechanical Engineering, which is the most closely related degree program. A number of new specialized courses are being developed to support the degree.

Examples of topics covered include:
* Fundamentals of Additive Manufacturing Processes
* Product Realization using Additive Manufacturing
* Design and Optimization for Additive Manufacturing
* Polymer processing for Additive Manufacturing
Learning outcomes include:
* understanding of material properties that govern use in AM processes
* understanding of manufacturing principles for AM
* understanding of design principles for AM
* ability to employ AM for prototyping and product realization
* ability to model AM processes
* ability to perform statistical analysis of AM processes