

**CLEMSON UNIVERSITY
COLLEGE OF ENGINEERING AND SCIENCE**

REQUESTING TO OFFER A NEW DEGREE PROGRAM

**MASTERS OF ENGINEERING
IN
SYSTEMS ENGINEERING**

Submitted to the South Carolina Commission on Higher Education
February 15, 2012



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CLEMSON UNIVERSITY

Masters of Engineering in Systems Engineering Full Proposal

Classification

Program Title	Systems Engineering
Academic Unit	College of Engineering and Sciences
Designation Type	Master of Engineering (M.Engr.)
Implementation Date	July 1, 2013
CIP Code	14.2701
Program	New
Site	Clemson University/Internet
Program qualifies for supplemental Palmetto Fellows Scholarship and LIFE Scholarship awards	No
Delivery Mode	Internet

Justification

Statement of the purposes and objectives of the program

The Masters of Engineering (M.Engr.) in Systems Engineering (SYSE) is a degree program intended to take advantage of the systems perspective pervasive in the departments of the College of Engineering and Science to allow working professionals to advance their careers in a field predicted to grow aggressively in the next few years. This interdisciplinary program allows students to develop a broad understanding of systems, focus those skills on one of eleven emphasis areas, and apply their knowledge in a practical project.

There are four primary goals for this program:

1. Take a leadership role in support of workforce development as it relates to creating next generation of system engineers to support industry and state needs. The program directly aligns with university's academic emphasis areas of Advanced Materials, Transportation, Information Technology, Health and Sustainable Environments.
2. Develop a close partnership with corporations across South Carolina but specifically in the Charleston area.
3. Add instructional and research coverage of a discipline that has only recently been available at Clemson through the Certificate in Systems Engineering.
4. Create a program structure that can be grown over the years to support the PhD programs in the participating departments.

Need for the program in the state

Systems engineers play an important role in large, complex, interdisciplinary projects prevalent in the types of industry that South Carolina would like to attract. System engineers ensure that such projects are properly defined, budgeted, and scheduled. Salaries for these positions are an average of \$76,000 according to one web site (www.glassdoor.com visited 1/22/2012) with an average starting salary of \$57,000.

The Masters of Engineering in Systems Engineering is intended to meet the expressed needs of South Carolina industries. Clemson currently offers a twelve hour graduate certificate in systems engineering that was instituted at the request of a number of South Carolina companies particularly those based in Charleston. Systems engineering is not broken out as a separate category by the Dept. of Labor but employment in systems and software engineering is expected to grow at well over 3% per year through 2018. It was rated the #1 Best Job in 2009 by CNN Money and is consistently in the top 50. Part of this rating concerns employment opportunities.

Systems engineers work in a variety of domains. A recent scan of systems engineering job postings found positions in avionics, health care, defense applications, telecommunications, power systems, and many others. This diversity means that employment as a system engineer is more robust than other more narrow engineering specialties. That scan also showed that those positions are with major employers including Boeing, Lockheed Martin, BAE Systems, and other project-oriented organizations. The recent arrival of the Boeing Corporation in Charleston and expansions of aircraft related re-engineering facilities in Greenville are just two examples of the increasing demand for systems engineers over the next several years.

The systems approach to problem solving is in increased demand as companies attempt to ship increasingly complex, sustainable products using innovative techniques and produced in less time. The systems engineer has a perspective that supports bringing together teams with diverse backgrounds to provide a complete solution to a customer's problem. They bridge the gap between management and technical personnel by translating customers' needs expressed in their vocabulary into the vocabulary understood by the engineering specialists. This requires training in techniques that bridge technical and managerial practices.

The program directly aligns with the university's emphasis areas which were chosen in part on the basis of societal need. The 11 programs participating in the curriculum committee all see systems engineering as having a role in their discipline.

Centrality of the program to the mission of the institution

The Masters of Engineering in Systems Engineering aligns well with the mission of Clemson University.

The mission of Clemson University is to fulfill the covenant between its founder and the people of South Carolina to establish a "high seminary of learning" through its historical land-grant responsibilities of teaching, research and extended public service.

The addition of the Systems Engineering curriculum is a public service offered in direct response to a request for service from several companies in South Carolina. The courses offered in this program will have direct ties to the research programs of eleven College of Engineering and Science's programs and to the industrial needs of South Carolina. The program will fuel the applied research programs of the College in areas such as ecology, environmental engineering and science, transportation, and information technology.

The curriculum blends a core of general systems knowledge and study in an emphasis area with a practical project based in a company local to the student. The university has established several emphasis areas:

- Manufacturing and Composites
- Software and Cybersecurity
- Transportation, Infrastructure
- Power Systems
- Health Systems
- Sustainable Systems

Systems engineers apply problem solving techniques to a wide range of technical problems. The Systems Engineering curriculum could potentially be of interest to students and researchers in all of these emphasis areas.

Relationship of the proposed program to other related programs within the institution

The Masters of Engineering in Systems Engineering is an outgrowth of the Systems Engineering certificate program. The four courses that make up the certificate will serve as the core systems engineering component of the master's program. The area of emphasis in the curriculum ties the masters program to a large number (11 at this point) of the disciplines represented in the College of Engineering and Science.

Most of the University's areas of emphasis are interdisciplinary programs that overlap the College of Engineering and Science's programs. This is exactly the types of domains in which systems engineers are in high demand. There has already been a student from the College of Arts and Architecture to take some of the courses in the systems engineering certificate.

Similarities or differences between the proposed program and those with similar objectives

The Masters of Engineering in Systems Engineering follows the International Council on Systems Engineering (INCOSE) proposed curriculum for systems engineering education. As such the core of the degree is very similar to other programs. However, the emphasis area requirement sets this program apart. By giving the student both the problem solving skills of systems engineering and the domain knowledge of a particular discipline, this program provides a broader base than that of many similar programs.

The Masters of Engineering in Systems Engineering will be the only one in the state. There are three programs in Georgia but one is a business management degree. There are two programs in North Carolina but one is an undergraduate degree and the other is a business management degree. Several online programs are offered. Only a couple are from peer institutions including Georgia Tech and Johns Hopkins. Bringing the strengths of the entire College of Engineering and Science to this program through the emphasis area will offer an attractive alternative to most available programs.

Enrollment

Admission Criteria

This degree is targeted at full time employees working in technical fields. The admissions criteria will be:

- 1) An undergraduate degree from an accredited institution
- 2) Math and problem solving skills equivalent to any of the following:
 - MTHSC 102 Introduction to Mathematical Analysis and MTHSC 207 Multi-Variate Calculus
 - MTHSC 106 Calculus of One Variable I and MTHSC 108 Calculus of One Variable II

MTHSC 106 Calculus of One Variable I and MTHSC 207 Multi-Variate Calculus

- 3) Industry experience

Projected Total Enrollment

Year	Fall		Spring		Summer	
	Headcount	Credit Hours	Headcount	Credit Hours	Headcount	Credit Hours
2012-2013	40	120	40	120	40	120
2013-2014	60	180	60	180	60	180
2014-2015	60	180	60	180	60	180
2015-2016	60	180	60	180	60	180
2016-2017	60	180	60	180	60	180

Estimated New Enrollment

Year	Fall		Spring		Summer	
	Headcount	Credit Hours	Headcount	Credit Hours	Headcount	Credit Hours
2012-2013	20	60	20	60	20	60
2013-2014	20	60	20	60	20	60
2014-2015	20	60	20	60	20	60
2015-2016	20	60	20	60	20	60
2016-2017	20	60	20	60	20	60

Curriculum

Requirements for Awarding of a Degree

The requirements for the degree are grouped into three categories:

1. A SYSE core of 12 hours made up of SYSE 801, 802, 803, and 853.
2. A 6 hour capstone project.
3. A SYSE emphasis area of 12 hours, chosen based on the individual's interests, in one of the suggested emphasis areas.

Courses suggested for the emphases:

- **Mechanical Engineering**
 - ME870 - Advanced design methods
 - ME871 - Engineering Optimization
 - ME873 - Integration through Optimization
 - ME655 - Design for Manufacturing
 - ME893 - Engineering Informatics
 - ME872 - Advanced Design Automation
- **EEES**
 - EE&S 686 Pollution Prevention and Industrial Ecology
 - EE&S 820 Environmental Systems Analysis
 - EE&S 812 Environmental Nuclear Engineering
 - EE&S 856 Pollution of the Aquatic Environment

- **Automotive Engineering**
 - AUE828 Fundamentals of Vehicle Drivelines and Powertrain Integration
 - AUE833 Automotive Manufacturing Process Development, Methods and Tools
 - AUE835 Automotive Electronics Integration
 - AUE880 Vehicle Design/Manufacture Project Management
 - AUE881 Automotive Systems: An Integrated Overview
 - AUE882 Systems Integration Concepts and Methods
 - AUE883 Applied Systems Integration
 - AUE887 Methods for Vehicle Testing

- **Industrial Engineering**
 - IE 684 Engineering Economic Analysis
 - IE 800 Human Factors Engineering
 - IE 657 Transportation and Logistics Engineering
 - IE 687 Industrial Safety

- **Chemical Engineering**
 - ChE/MSE/ME 645 Introduction to Fiber and Film Systems (jointly taught with Gary Lickfield, MSE)
 - ChE 818 Advanced Polymer Processing
 - ChE820 (845 for now) Polymeric Composite Materials.

- **Materials Science**
 - MS&E 613 Non-crystalline Solids
 - MS&E 615 Introduction to Polymer Science and Engineering
 - MS&E 622 Mechanical Behavior of Materials
 - MS&E 624 Optical Materials and Their Applications
 - ExSt 801 STATISTICAL METHODS I

- **School of Computing**
 - CPSC 871 Foundations of Software Engineering
 - CP SC 877 Fundamentals of Biometric Systems
 - CP SC 830 Systems Modeling
 - HCC 831 Fundamentals of Human-Centered Computing
 - CP SC 855 Embedded Network Systems

- **ECE**
 - ECE 847 Digital Image Processing
 - ECE 655 Robot Manipulators
 - ECE 855 Artificial Intelligence
 - ECE 856 Pattern Recognition
 - ECE 667 Introduction to Digital Signal Processing

New Courses

Several new courses required for the degree have already been added to support the certificate in Systems Engineering. The areas of emphasis are currently constituted, as listed above, from existing courses. These areas will evolve as the disciplines themselves evolve and serve the students of these other program as well as the SYSE students.

The courses added to support the certificate include:

- SYSE 801 – Systems Engineering 1 - The focus of this course is to educate the student on the complete system design process using a project oriented format. The course consists of topical areas in the following: needs analysis, concept generation and development, prototyping, evaluation, cost analysis, implementation and delivery.
- SYSE 802 – Systems Engineering 2 - Analysis and design of complex systems will be addressed by considering the human, hardware, and software components of the system. Techniques for unambiguously defining a problem and designing a solution will be applied to a model problem. Architectural techniques will be used to assemble a solution that satisfies functional and non-functional requirements. A range of qualitative and quantitative verification and validation techniques for evaluating the fitness of a solution will be examined and used.
- SYSE 803 - The Systems Engineering Project Manager is responsible to the project stakeholders and the project advocate, and ensures that the project meets metrics related to cost, schedule, performance and scope. This course provides the framework for managing projects using a systems engineering framework, emphasizing the Project Management Institute's body of knowledge.
- SYSE 853 - Improving Systems Using Quality and Lean Principles - The focus of this course is to educate students in the theory of quality control, its principles and the application of Quality and Lean techniques to manufacturing and service systems.
- Capstone Course

The capstone project course is the only course that has been added specifically to support the masters degree.

SYSE 859 - Capstone Project - Capstone experience in the analysis and design of systems by carrying out a substantial project.

No other SYSE courses are planned. As the discipline evolves, the curriculum will be re-evaluated by the curriculum committee responsible for the degree.

Assessment Plan

Objective: The M.Engr. SYSE degree program prepares graduates for placement and effective performance in technical positions that require the coordination of diverse skill sets to design complex systems.

Means of Assessment

Exit interviews, employer surveys, and alumni surveys

Criteria for Success

80% of graduates employed in their field will respond that they were prepared.

Outcome 1: Students in the M.Engr. SYSE program will attain an ability to apply knowledge of systems engineering methodologies and tools to the design, development, implementation, and improvement of solutions to a diverse array of systems.

Means of Assessment

The student's ability to apply knowledge will be measured during the student's capstone project.

Criteria for Success

We will be successful when 80% or more of the MEngSYSE graduates are judged to have that ability.

Outcome 2: Students in the MEng SYSE program will attain an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Means of Assessment

The student's ability to use the techniques, skills, and modern engineering tools will be evaluated during the student's capstone project.

Criteria for Success

We will be successful when 80% or more of the MEngSYSE graduates are judged to have that ability.

Outcome 3: Students in the MEngSYSE program will attain an ability to design and conduct experiments, as well as to analyze and interpret data.

Means of Assessment

The students' ability to design and conduct experiments, as well as to analyze and interpret data will be measured through interviews upon completion of the capstone project and through surveys of alumni of the program.

Criteria for Success

We will be successful when 80% or more of the MEngSYSE graduates are judged to have that ability.

Faculty

The College of Engineering and Science has established an interdisciplinary curriculum committee to oversee the Systems Engineering Masters program. These will also be the primary faculty supporting the program. There is no plan to add new faculty and staff as a result of this program. On a semester by semester basis, the Program Director working with the Department

Chairs will determine if the courses being taught by Clemson faculty will be part of their regular teaching load for that semester or if the class will be taught as an overload and compensated with dual pay. The faculty is listed in the table below.

List Staff by Rank (e.g. Professor #1, Professor #2, Associate Professor #1, etc)	Highest Degree Earned	Field of Study	Teaching in Field (Yes/No)
Associate Professor #1	PhD	Mathematics	No
Associate Professor #2	PhD	Mechanical Engineering	Yes
Assistant Professor #1	PhD	Mechanical Engineering	Yes
Professor #1	PhD	Electrical Engineering	Yes
Assistant Professor #2	PhD	Mechanical Engineering	Yes
Associate Professor #3	PhD	Bio-medical Engineering	Yes
Professor #2	PhD	Fibers and Films	Yes
Assistant Professor #3	PhD	Materials Science	Yes
Professor #3	PhD	Geochemistry	Yes
Professor #4	PhD	Mathematics	Yes

Unit Administration/Faculty/Staff Support

Year	New		Existing		Total	
	Headcount	FTE	Headcount	FTE	Headcount	FTE
Administration						
2012-2013	0	0	1	0.25	1	0.25
2013-2014	0	0	1	0.25	1	0.25
2014-2015	0	0	1	0.25	1	0.25
2015-2016	0	0	1	0.25	1	0.25
2016-2017	0	0	1	0.25	1	0.25

Year	New		Existing		Total	
	Headcount	FTE	Headcount	FTE	Headcount	FTE
Faculty						
2012-2013	0	0	6	1.5	6	1.5
2013-2014	0	0	9	2.25	9	2.25
2014-2015	0	0	10	2.50	10	2.50
2015-2016	0	0	10	2.50	10	2.50
2016-2017	0	0	10	2.50	10	2.50
Staff						
2012-2013	0	0	2	1.0	2	1.0
2013-2014	0	0	2	1.0	2	1.0
2014-2015	0	0	2	1.0	2	1.0
2015-2016	0	0	2	1.0	2	1.0
2016-2017	0	0	2	1.0	2	1.0

Physical Plant

As an Internet only program, there are no physical plant requirements or usage beyond the office space needed for professors and staff. Clemson University has a world-class Internet connection and will provide very good service to the students in the program.

Equipment

There are no additional major equipment items needed to support the proposed Systems Engineering M.Engr. SYSE degree.

Library Resources

The proposed Systems Engineering M.Engr. SYSE degree integrates existing units/courses across campus to form a unique degree program. As such, the library resources required for the

proposed Systems Engineering M.Engr. SYSE degree are already in place; therefore, there is no need for additional library resources. Students in the program will have access to the electronic journals available to all Clemson students through the Internet.

Accreditation, Approval, Licensure, or Certification

The proposed Systems Engineering M.Engr. SYSE is not subject to specialized or professional accreditation or approval by any state agency other than the Commission.

Articulation

There are no formal arrangements with any other institution; however, one student taking the SYSE 802 course during the Fall 2011 semester intended to transfer those hours to the Citadel as part of her Certificate in Systems Engineering Management. Initial discussions have been held to allow Clemson students interested in an emphasis area in management to take a course or courses at the Citadel and for those Citadel students interested in some technical systems engineering courses to attend Clemson via the online courses.

Costs

COSTS TO THE INSTITUTION

ESTIMATED COSTS BY YEAR						
Category	Year #1	Year #2	Year #3	Year #4	Year #5	TOTALS
Program Administration	New	33,660	26,000	22,927	24,765	154,052
Faculty Salaries	60,000	105,000	150,000	150,000	150,000	615,000
Graduate Assistants	16,000	38,000	40,000	42,500	40,000	176,500
Clerical/Support Personnel	20,200	20,840	21,500	22,073	22,735	107,348
Supplies and Materials Library Resources	7,500	7,500	7,500	7,500	7,500	37,500
Equipment	28,600	14,000	14,000	14,000	14,000	84,600
Facilities	1,000	1,000	1,000	1,000	1,000	5,000
Other (Identify)						
TOTALS	180,000	220,000	260,000	260,000	260,000	1,180,000
SOURCES OF FINANCING BY YEAR						
Tuition Funding	135,000	135,000	135,000	135,000	135,000	675,000
Other State Funding						
Reallocation of Existing						
Federal Funding						
Other Funding* (Endowments from Companies and Educational Grants)	45000	85000	125000	125000	125000	505000
TOTALS	180,000	220,000	260,000	260,000	260,000	1,180,000

* Private endowments from companies who have indicated significant interest in the development of the new program and through funds from competitive educational grants.

Institutional Approval

The initial SYSE program proposal was approved by the Clemson University Board of Trustees on October 20, 2011.

The SYSE program was approved by the SYSE Curriculum Committee on December 1, 2011.

The SYSE program was approved by the College of Engineering and Sciences Curriculum Committee on December 13, 2011.

The SYSE program was read at the Feb 10, 2012 meeting and is slated for approval at the March 9, 2012 Clemson University Curriculum Committee.