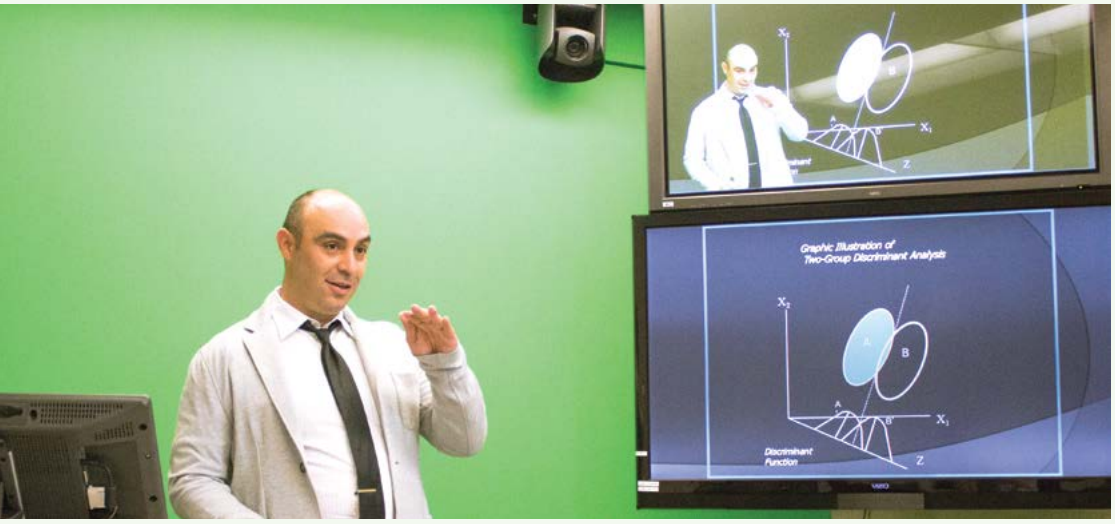
2016 - 2017

# SYSTEMS ENGINEERING

## Distance graduate degrees & certificate programs




MISSOURI S&T

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MISSOURI S&T

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# Missouri University of Science and Technology

## One of the nation's top technological research universities

One of four campuses in the University of Missouri System, Missouri University of Science and Technology was founded in 1870 as the University of Missouri School of Mines and Metallurgy and was the first technological institution west of the Mississippi. In 1964, it became the University of Missouri-Rolla (UMR). In 2008, UMR became Missouri University of Science and Technology (Missouri S&T) to better reflect its mission and national reputation as a top technological research university.

Missouri S&T is one of the nation's leading universities in educating engineers. It offers a broad range of degree programs that are science and technology-based, with heavy emphasis on interdisciplinary research through its research centers and institutes.

To meet the needs of working professionals, Missouri S&T offers 17 master's degrees and over 50 graduate certificate programs through its nationally ranked online graduate programs. A limited number of PhDs are available in select areas.

Missouri S&T graduates have a long and distinguished history as leaders in engineering, technology, management, entrepreneurship, education, the arts and humanities, medicine and science. Its alumni include astronauts, dozens of inventors and Fortune 500 executives, hundreds of entrepreneurs, novelists, and an Academy Award-winning engineer.

Missouri S&T is an active leader in systems engineering and architecting research, conferences and other professional activities, including INCOSE, IISE, and IEEE. As one of the leading systems engineering programs in the nation, Missouri S&T is the only university in the world to have four Stevens Doctoral Award recipients, and one of its systems engineering faculty is the former chair of INCOSE Fellows.

Diversity of engineering specialization, technological diversity, and strong interdisciplinary research make Missouri S&T an ideal place for its Systems Engineering Graduate Program to be the leader in systems engineering education and research, both nationally and internationally.

World-changing research occurs every day at S&T. Key research areas include biomedical science and engineering, civil infrastructure, energy research and development, environmental research, intelligent systems, materials research, and rock mechanics and explosives. Future-focused research will be carried out in S&T's four signature research areas:

### Advanced Materials for Sustainable Infrastructure

This signature area plays a critical role in improving the nation's existing transportation, nuclear and utility infrastructure in an environmentally sustainable manner.

### Advanced Manufacturing

Missouri S&T faculty are among the nation's best in this emerging field, which is an important driver of our nation's economy.

### Enabling Materials for Extreme Environments

This area involves the creation of ceramics and composites to withstand concentrated solar power, nuclear fusion, hypersonic flight, rocket propulsion and ballistic impact.

### Smart Living

This signature area intersects engineering, the social sciences and humanities by seamlessly transforming home, workplace, transportation and energy infrastructures into "smart" environments to improve quality of life. Smart Living combines participatory sensing, social behavior analysis, data analytics, engineering and technology into one integrated concept.

# Missouri S&T and Systems Engineering

**The Systems Engineering Graduate Program** builds on sound engineering undergraduate education and experience, and maintains engineering specialization diversity in its graduates at both the M.S. and Ph.D. levels.

**Systems engineering research** is supported by interdisciplinary research and collaboration. Research areas include: Cyber Physical Systems, Systems Architecting, Computational Intelligence, Model Based Systems Engineering, Sustainable Infrastructure.

**Missouri S&T's Smart Engineering Systems Lab (SESL)** develops new models and tools for building complex systems architectures that are intelligent, modular, and adaptive and contributes heavily to systems architecting research. The engineering tools and algorithms that are developed by the interdisciplinary teams can be used in building today's complex systems.

**Research Challenges.** The Systems Engineering Graduate Program, along with its more than 500 graduates, contributes to the research challenges of systems engineering imposed by today's complex, adaptive, distributed, cooperative, and dynamically changing engineering systems.

**SERC-UARC.** Missouri S&T is one of 23 collaborating universities that participate in this university affiliated research center supported by the Department of Defense. Department faculty serve as Principal Investigator and Co-Principal Investigator on SERC sponsored projects. Missouri S&T heavily contributes enterprises and system of systems vision of SERC. System of Systems Analysis and Architecting and Flexible Intelligent Learning Architectures for SoS FILA-SoS are projects led by Missouri S&T SERC Senior Principal Investigator.

**Faculty and Teaching Philosophy.** Missouri S&T, through its modular and adaptive Systems Engineering (MS) degree program and world-renowned faculty, responds to the needs of engineering students throughout the world. Since 2000,over 500 Boeing students have graduated from the systems engineering program. Our faculty include two of the 72 INCOSE Fellows contributing to systems engineering research and education.

**The systems engineering pedagogy** is to expose students to the wide range of influences that program managers and engineers face in real programs, along with engineering tools that are needed to produce the best balanced development of today's complex systems, while incorporating "real-world" problems that expand the students knowledge base in the area of "system life-cycle."

**Students are exposed to a variety of opinions, tools and methodologies.** The end point of the inclusion of design prototyping, electronics, software development and validation from a real world customer is a more personal understanding of the process and results of systems engineering realities. This is achieved through project teams consisting of faculty advisors, industry mentors, and Ph.D. students.

**Complex Adaptive Systems Conference.** For the past twenty-five years, Missouri S&T has provided a forum for international researchers who are interested in Computational Intelligence. This strong leadership for two decades in applied Computational Intelligence is an asset in designing and operating complex systems of the future.

**National Science Foundation Industry/ University Cooperative Research Center (NSF I/UCRC) on Intelligent Maintenance Systems.** This center is supported by The Boeing Company, as well as Caterpillar, Festo, Chevron, 21st Century, AVETEC, TRW Military and Honeywell in the areas of Sensing and Monitoring, Prognostics, and Advanced Simulation. The NSF I/UCRC is one of the research units of the Systems Engineering Graduate Program.

**The Energy Research & Development Center (ERDC)** serves as a focal point for research, development, and deployment activities related to energy-related technologies and energy security. ERDC researchers focus on educating students to analyze and solve issues related to environmental and economic sustainability of energy systems that improve rural economies and expand resource diversity.

**Center for Aerospace Manufacturing Technologies (CAMT).** This center is a collaboration of Missouri S&T and its industrial consortium. The mission of CAMT is to serve as a center of excellence to research, develop, evaluate and demonstrate new and optimal methodologies and tools for the rapid and cost-effective manufacture of aerospace components and products and to promote new education and training programs for the evolving aerospace manufacturing workforce, resulting in significant technological advancement and national economic impact.

**Center for Infrastructure Engineering Studies.** This center provides research expertise in the areas of building and civil infrastructure, such as roads and bridges, power infrastructure, and infrastructure management.

**National Center of Academic Excellence in Information Assurance Research.** Missouri S&T is the only university in Missouri with this active designation and is one of 56 schools in the nation.

**Missouri S&T's state-of-the-art Video Communications Center (VCC).** The VCC allows distance students to participate synchronously and asynchronously in class from anywhere in the world. Through two-way audio/video, digital technologies, studio classrooms and a unique set of video streaming standards, the VCC makes the location of the student and professor transparent in education.

**Missouri S&T's Global Learning** brings the teaching, research and service capabilities of Missouri S&T to a global market. Through its programs, you can earn a graduate degree or certificate through distance education, or attend a technical conference for continuing education credit. Through live streaming video, collaborative software and archived classes, S&T provides an education that fits the needs of working professionals.

# Requirements for Admissions

The Master's Degree Program requires the successful completion of six core courses and four approved specialization track courses or graduate certificate courses.

The Graduate Certificate Program requires satisfactory completion of four courses.

Systems Engineering Core Courses address fundamental systems engineering topics, concepts and principles and complex system management.

In addition, there is a course addressing economic decision analysis to reflect the reality that program decisions consisting of the total life cycle must include a proper understanding of economic consequences.

The Specialization Tracks provide you with the ability to address your technology education needs in the context of the overall Systems Engineering program. Some specialization tracks include computational intelligence, communication systems, computer security and reliability, economic decision analysis and financial engineering, engineering management, information science and technology, information systems and computer architecture, network centric systems, quality and reliability engineering, software engineering, systems and design optimization and systems safety and security. With the permission of the program director, a student may propose a different field other than those shown, or a combination of shown fields, and have it accepted, if it meets the program and university criteria.

Almost 90 percent of students start in the Systems Engineering Graduate Certificate Program. Certificate courses taken for graduate credit can apply to the M.S. degree, once accepted into the degree program. If the four-course sequence is completed with a grade of "B" or better (3.0 or greater) in each of the courses taken, students can be admitted to the master's program in systems engineering without taking the GRE. The certificate program may be followed by six additional three credit hour courses to complete the M.S. degree. Once admitted to the program, students must take the designated courses to receive the graduate certificate.

## Admission Requirements for Graduate Certificate

- A bachelor's degree in engineering or physical science
- Satisfactory Cumulative Undergraduate GPA (2.75 for regular status)
- Minimum of 12 months of work experience preferred, or currently accepted into the graduate degree program at Missouri S&T

For current enrollment requirements, go online to http://dce.mst.edu/credit/degrees/systems.html.

## SPECIALIZATION TRACK **SUBSTITUTION OPTION**

One of the following graduate certificates may be substituted for a specialization track with the permission of the program director.

**Civil and Environmental**
Contemporary Structural Engineering
Geoenvironmental Engineering
Infrastructure Renewal
Project Engineering and Construction Management

**Computer Science**
Big Data Management and Analytics
Big Data Management and Security
Computational Intelligence
Information Assurance & Security Officer Essentials
Information Systems & Cloud Computing
Software Design & Development
Systems and Software Architecture
Wireless Networks and Mobile Systems

**Electrical & Computer Engineering**
Computational Intelligence
Electric Machines and Drives
Electric Power Systems Engineering
Information Assurance & Security Officer Essentials
Network Centric Systems

**Engineering Management**
Engineering Management
Financial Engineering
Human Systems Integration
Leadership in Engineering Organizations
Lean Six Sigma
Project Engineering and Construction Management
Project Management
Safety Engineering

**Manufacturing Engineering**
CAD/CAM & Rapid Product Realization
Manufacturing Systems

**Mechanical and Aerospace Engineering**
Composite Materials and Structures
Control Systems
Energy Conversion & Transport
Engineering Mechanics
Manufacturing Automation

# Requirements for Completion

## M.S. in Systems Engineering

**dce.mst.edu/credit/degrees/systems/**

A minimum of 30 credits of coursework from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a C grade or better in each course.

Accumulation of more than 9 hours of C or F results in dismissal from the program. A maximum of nine units may be transferred from other universities if taken for graduate credit with a B or better and equitable to a course at Missouri S&T. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. There is no thesis or comprehensive examination requirement. It is the responsibility of each student to apply for graduation with the Missouri S&T Registrar's Office during his or her last semester. Assistance on this final step can be provided by the Engineering Management and Systems Engineering (EMSE) Department, if necessary. More details about requirements can be found in the university catalog (online at catalog.mst.edu) and are available from EMSE upon request. Details about the program can also be found at emse.mst.edu.

### Systems Engineering Domain Specific Graduate Certificates

- Systems Engineering
- Network Centric Systems
- Computational Intelligence
- Model Based Systems Engineering
- Big Data Management and Analytics*
- Big Data Management and Security*
- Software Design and Development*
- Systems and Software Architecture*

The graduate certificate programs consist of four core courses and are designed for working professionals. Certificate courses taken for graduate credit can apply to the M.S. degree, if the student applies and is admitted. The 12 credits of coursework from the certificate courses must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a B grade or better in each course. **If the four-course sequence is completed with a grade of B or better in each of the courses taken, students can be admitted to the M.S. program in Systems Engineering without taking the GRE when they apply for the M.S.** To complete the M.S. degree, you must take six additional three-credit courses.

**Acceptance to this certificate program is through Computer Science. It may be used as part of your specialization track for Systems Engineering and courses may count toward the degree program.*

# MS Core Courses

## Systems Architecting and Analysis

**SYS ENG 5101 System Engineering and Analysis (LEC 3.0)**
The concepts of Systems Engineering are introduced through a project. Students work in virtual teams. The topics covered are architecture development, basic system architectural design techniques, functional decomposition, design and technical review objectives, and initial specifications. Prerequisite: graduate or senior standing.

**SYS ENG 6102 Information Based Design (LEC 3.0)**
This course is an introduction to the use of common data analytical methods and analysis for the purpose of decision making during the design phase of engineering system development. Through the introduction to such analytical methodologies, the systems engineering tool belt is made more effective as it is the foundation to decision analysis. Prerequisite: graduate standing.

**SYS ENG 6104 Systems Architecting (LEC 3.0)**
Tools and concepts of architecting complex engineering systems. Ambiguity in Systems Architecting and Fuzzy Systems; Search as an Architecting Process; Architecting Heuristics; Systems Scoping and Attribute Selection; Assessing Architectures; Systems Aggregation, Partitioning; Systems Behavior Generation; System Science and Thinking, Cyber Physical Systems. Prerequisite: graduate standing.

## Complex Systems Management

**SYS ENG 6103 Economic Analysis for Systems Engineering (LEC 3.0)**
Methods of economic evaluation for engineering projects involving complex systems. Economic impacts on choosing system alternatives, life cycle costing, economic decisions involving risk and uncertainty, and engineering cost estimation for projects in government, defense, and commercial industries Prerequisite: graduate standing.

**SYS ENG 6105 Complex Engineering Systems Project Management (LEC 3.0)**
The course topics include issues specific to distributed project management, team development, resource management, constraint planning, development of Integrated Master Schedule and Integrated Master Plan, monitoring technical performance, schedule, cost, and risk. Prerequisite: graduate standing.

**SYS ENG 6196 Systems Engineering Capstone (LEC 3.0)**
The topics covered are Systems Engineering Management Plan (SEMP), Systems Engineering processes, process re-engineering, standards, and systems engineering case studies. Students will apply the skills and theory that they mastered in previous five core courses to the analysis of assigned cases. Prerequisites: Sys Eng 6105.

*The information contained in this document is subject to change, and classes listed may not be offered each semester. If there are any questions regarding your program of interest, please refer to the university's website, or contact the program director directly.*

# Systems Engineering, Network Centric Systems, Systems and Software Architecture and Model Based Systems Engineering

## Systems Engineering

**dce.mst.edu/credit/certificates/syseng/**

The Graduate Certificate in Systems Engineering is designed to provide graduate engineers with the advanced knowledge and skills necessary for the conception and implementation of complex systems. The emphasis is on the processes by which complex systems are conceived, planned, designed, built, tested, and certified. The systems engineering experience can be applied to defense, space, aircraft, communications, navigation, sensor, computer software, computer hardware, transportation, and other aerospace and commercial activities. The graduate courses selected for the program will count toward an M.S. degree in Systems Engineering. Graduate certificate students will be admitted to the M.S. program in Systems Engineering, if they complete the four course sequence, namely; Sys Eng 5101, 6102, 6103, and 6104 with a grade of B or better in each course taken.

### Core Courses:

SYS ENG 5101 Systems Engineering and Analysis
SYS ENG 6102 Information Based Design
SYS ENG 6103 Economic Analysis for Systems Engineering
SYS ENG 6104 Systems Architecting

## Network Centric Systems

**dce.mst.edu/credit/certificates/networkcentric/**

The area of Network Centric Systems has evolved from recent advances in information technology and the increased level of interconnectivity that society has achieved through the Internet and Broadband communication technology. The area of Network Centric Systems has grown due to advances in information technology and increases in connectivity due to the convergence of computing and communications.

Network Centric Systems are frequently "Systems of Systems" with complex interfaces and interactions. The Graduate Certificate in Network Centric Systems is a joint effort between Computer Engineering and Systems Engineering. It provides practicing engineers with the necessary skills to develop and design the operation of network centric systems. The graduate courses selected for the program will count toward an M.S. degree in Systems Engineering or Computer Engineering and they address the intersection between network engineering and systems engineering and architecting. The requirements are the successful completion of a core course and three elective courses. (A grade of B or better is required in each course before the student is eligible for the master of science program.)

### Network Centric Systems Core Course:

The following course is required:

SYS ENG 6321/COMP ENG 6410 Modeling Complex Systems (LEC 3.0) Engineering Systems of today are non-linear, distributed, global, and adaptive to their environment in both space and time, thereby creating emergent behaviors. This course covers the current modeling tools and techniques used in modeling and architecting these complex systems. *Prerequisite: graduate standing.*

### Elective Courses:

Select three courses from the following:

COMP ENG 5510 Fault-Tolerant Digital Systems (LEC 3.0)
Design and analysis of fault-tolerant digital systems, with an emphasis on reliability, survivability, and recovery techniques. *Prerequisite: Comp Eng 2210/Comp Eng 2211 or equivalent introductory computer engineering course.*

COMP ENG 5410 Introduction to Computer Communication Networks (LEC 3.0) Design of computer networks with emphasis on network architecture, protocols and standards, performance considerations, and network technologies. Topics include: LAN, MAN, WAN, congestion/ flow/error control, routing, addressing, broadcasting, multicasting, switching, and internetworking. A modeling tool is used for network design and simulation. *Prerequisite: Comp Eng 3550 or computer hardware competency.*

COMP ENG 5420 Introduction to Network Security (LEC 3.0)
This course examines basic issues in network management, testing, and security; it also discusses key encryption, key management, authentication, intrusion detection, malicious attack, and insider threats. Security of electronic mail and electronic commerce systems is also presented. *Prerequisite: Comp Eng 5410 or Comp Sci 4601.*

COMP ENG 5430/SYS ENG 5323 Wireless Networks (LAB 1.0 and LEC 2.0)
Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and ad hoc and sensor networks. *Prerequisites: hardware competency, Elec Eng 3420 or Comp Eng 3550 and graduate standing.*

SYS ENG 6322/COMP ENG 6510 Resilient Networks (LEC 3.0)
This course presents reliability and fault tolerance for network-centric systems, including models, metrics, and analysis techniques. This course also concentrates on security, including technical tools and methods for audit and assessment as well as management and policy issues. *Prerequisite: Sys Eng 6321/Comp Eng 6410 or Comp Eng 5420.*

COMP ENG 6420/SYS ENG 6324 Wireless Ad hoc and Sensor Networks (LEC 3.0)
Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. *Prerequisite: Comp Eng 5430/Sys Eng 5323 (Wireless Networks), or Comp Eng 5420, or consent of instructor.*

COMP ENG 6430 High Speed Networks (LAB 1.0 and LEC 2.0)
State-of-the-art survey of high-speed networks, modeling and simulation, quality of service (QoS) for multimedia applications and management schemes, TCP congestion control, ATM and Internet traffic management, Internet Service Architecture (ISA), and Internet routing protocols. *Prerequisites: Comp Eng 5410 and hardware competency for ECE students, Comp Sci 4600 for the computer science students, or consent of the instructor.*

COMP SCI 6600 Computer Security (LEC 3.0)
The course presents various vulnerabilities and threats to information in cyberspace and the principles and techniques for preventing and detecting threats, and recovering from attacks. The course deals with various aspects and layers of security: data-level, network-level, system-level, and application-level security. *Prerequisites: A grade of C or better in both Comp Sci 3600 and 5200.*

COMP SCI 6604 Mobile And Sensor Data Management (LEC 3.0)
Architectures of mobile computing systems: Mobile-IP support in mobile computing systems; location data management, broadcasting and indexing, replication control; caching, fault tolerance and reliability of mobile systems; ad hoc and sensor routing schemes; key management. *Prerequisite: Comp Sci 4601.*

## Computational Intelligence

**dce.mst.edu/credit/certificates/computationalintelligence/index.html**

Recent advances in information technology and the increased level of interconnectivity that society has achieved through Internet and broadband communication technology created systems that are very much different. The world is facing an increasing level of systems integration leading toward Systems of Systems (SoS) that adapt to changing environmental conditions. The number of connections between components, the diversity of the components and the way the components are organized can lead to different emergent system behavior. Computational Intelligence tools are an integral part of these systems in enabling adaptive capability in their design and operation.

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use and development of computational intelligence algorithms based on evolutionary computation, neural networks, fuzzy logic, and complex systems theory. Engineers can also learn how to integrate common sense reasoning with computational intelligence elective courses such as data mining and knowledge discovery.

### Core Courses:

COMP ENG 5310/ ELEC ENG 5310/SYS ENG 5211 Computational Intelligence (LEC 3.0)
Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application, case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. P*rerequisite: Comp Sci 1510 or programming competency.*

And select one of the following:

SYS ENG 5212/ELEC ENG 5370 Introduction to Neural Networks and Applications (LEC 3.0)
The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. *Prerequisites: graduate standing.*

COMP SCI 5401 Evolutionary Computing (LEC 3.0)
Introduces evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory (e.g., genetic algorithms), capable of solving complex problems for which other techniques fail. Students will implement course concepts, tackling science, engineering and/or business problems. *Prerequisites: Comp Sci 2500 and a statistics course.*

COMP SCI 5400 Introduction to Artificial Intelligence (LEC 3.0)
A modern introduction to AI, covering important topics of current interest such as search algorithms, heuristics, game trees, knowledge representation, reasoning, computational intelligence, and machine learning. Students will implement course concepts covering selected AI topics.
*Prerequisite: Comp Sci 2500.*

## Elective Courses:

Select two courses not taken as a core course:

COMP SCI 5400 Introduction To Artificial Intelligence (LEC 3.0)
*(Refer to course description provided above.)*

COMP SCI 5401 Evolutionary Computing (LEC 3.0)
*(Refer to course description provided above.)*

COMP ENG 6330/ELEC ENG 6340/SYS ENG 6214/STAT 6239 Clustering Algorithms (LEC 3.0)
An introduction to the cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. *Prerequisites: At least one graduate course in statistics, data mining, algorithms, computational intelligence, neural networks, consistent with student's degree program.*

COMP SCI 6400 Advanced Topics in Artificial Intelligence ( LEC 3.0)
Advanced topics of current interest in the field of artificial intelligence. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. *Prerequisite: Comp Sci 5400 or Comp Sci 5401 or Comp Eng 5310.*

COMP SCI 6401 Advanced Evolutionary Computing (LEC 3.0)
Advanced topics in evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory, capable of solving complex problems for which other techniques fail. Students will conduct challenging research projects involving advanced concept implementation, empirical studies, statistical analysis, and paper writing. *Prerequisite: Comp Sci 5401.*

SYS ENG 6215/COMP ENG 6320/ELEC ENG 6360 Adaptive Dynamic Programming (LEC 3.0)
Review of Neurocontrol and Optimization, introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), combined concepts of ADP and RL, Heuristic Dynamic Programming (HDP), Duel Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP) and case studies. *Prerequisite: Sys Eng 5212/Elec Eng 5370.*

SYS ENG 6216 Advanced Topics in Data Mining (3.0)
Data mining and knowledge discovery utilizes both classical and new algorithms, such as machine learning and neural networks, to discover previously unknown relationships in data. Key data mining issues to be addressed include knowledge representation and knowledge acquisition (automated learning).

ELEC ENG 5320 Neural Networks for Control (LEC 3.0)
Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of control. Case studies and a term project.

SYS ENG 5212/ELEC ENG 5370 Introduction to Neural Networks and Applications *(Course description is provided on page 9)*

COMP ENG 6310/MECH ENG 6447/AERO ENG 6447/ENG MGT 6410/COMP SCI 6202 Markov Decision Processes (LEC 3.0)
Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics.

SYS ENG 6213 Advanced Neural Networks (LEC 3.0)
Advanced artificial neural network architectures, namely; Radial-Basis Function Networks, Support Vector Machines, Committee Machines, Principal Components Analysis, Information-Theoretic Models, Stochastic Machines, Neurodynamic Programming, Temporal Processing are the topics covered. *Prerequisite: Sys Eng 5212 or equivalent neural network course.*

# Model Based Systems Engineering

**dce.mst.edu/credit/certificates/modelbasedsystemsengineering/**

Recent advances in technology demands and the increased level of interconnectivity achieved through Internet and broadband communication technology is leading to systems that are increasingly complex. To manage this complexity, computational modeling and data resources have become nearly ubiquitous in Systems Engineering, driving the profession from a document-centric paradigm to a model-centric one. Model Based Systems Engineering provides the means to construct models that capture system structure, behavior, and requirements and maintain consistency of these models automatically between collaborating engineers. These models can then be used in tandem with engineering and mathematics tools to quickly gain insight into the overall system performance over the entire lifecycle before a system component is ever made.

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use of current modeling techniques to develop and simulate complex, multi-disciplinary engineering systems. In addition, engineers will learn methods to automate data acquisition for system development, establish rules for reusability of model resources, and acquire necessary skills for simulating the designed systems.

SYS ENG 6541 Distributed Systems Modeling (LEC 3.0)
This course will discuss issues related to distributed systems architecting, modeling, analysis and representation, with specific focus on discrete-part manufacturing domain. Distributed modeling techniques and other model decomposition methods using simulation modeling and scalability issues will also be addressed.

SYS ENG 6542 Model Based Systems Engineering (LEC 3.0)
Provides the student with understanding of the use of models to represent systems and validate system architectures. The student will gain proficiency in using a systems modeling language and shifting systems engineering from a document centric to a model centric paradigm. *Prerequisites: Graduate Standing. (Co-listed with COMP SCI 6102)*

SYS ENG 6239 Smart Engineering System Design (LEC 3.0)
Covers the tools, techniques and methods used in developing Flexible Intelligent Learning Architectures for system of systems (SoS) and cyber physical systems (CPS) through evolutionary approach. Meta-architecture generation algorithms, SoS and CPS architecture evaluation methods, executable architectures, many meta-architecture objectives trade. *Prerequisite: graduate standing.*

ENG MGT 5411 Engineering Design Optimization (LEC 3.0)
This course is an introduction to the theory and practice of optimal design as an element of the engineering design process. The use of optimization as a tool in the various stages of product realization and management of engineering and manufacturing activities is stressed. The course stresses the application of nonlinear programming methods. *Prerequisite: Math 3304 or 3329.*

## Software Design and Development

dce.mst.edu/credit/certificates/softwaredesigndev/

The Software Design and Development Certificate provides an attractive option for working professionals to expand their knowledge in Software Engineering. The core courses give an overview of software project management and its many roles, from overall project management and process improvement to the management of individual lifecycle components, including software deployment and evolution. Specialized coursework gives depth in advanced object-oriented design, requirements, software quality and testing theory and practice and an advanced treatment of software metrics.

COMP SCI 5101 Software Testing and Quality Assurance
COMP SCI 5102 Object-Oriented Analysis and Design
COMP SCI 6100 Software Engineering II
COMP SCI 6101 Software Requirements Engineering

## Systems and Software Architecture

dce.mst.edu/credit/certificates/systemssoftwarearchitecture/index.html

The systems and software architect fills a critical role in today's development process, transforming market inputs into the requirements and architecture specification of a product such that independent (often remote) development teams could implement. A focused graduate certificate training program on Systems and Software Architecting has been requested from various industrial partners.

SYS ENG 6542 Model Based Systems Engineering
*(Refer to course description above.)*

SYS ENG 6167 Software Intensive Systems Architecting (LEC 3.0)
The basic tools and concepts of architecting complex software intensive systems are introduced. The following topics are covered under four main sections, namely; Architecting Process, Architecting Heuristics, Architecting Patterns and Frameworks, and Architecture Assessment.

COMP SCI 5102 Object-Oriented Analysis and Design (LEC 3.0)
This course will explore principles, mechanisms, and methodologies in object-oriented analysis and design. An object-oriented programming language will be used as the vehicle for the exploration. *Prerequisite: Comp Sci 2500.*

COMP SCI 6101 Software Requirements Engineering (LEC 3.0)
This course will cover advanced methods, processes, and technique for discovering, analyzing, specifying and managing software requirements of a software system from multiple perspectives. It will discuss both functional and non-functional requirements analysis. *Prerequisite: A grade of "C" or better in Comp Sci 3100.*

## Information Assurance & Security Officer Essentials

dce.mst.edu/credit/certificates/informationassuranceandsecurityofficer/index.html

Protecting information systems is key to protecting the nation's critical infrastructures. Only through diligence and a well-trained work force will we be able to adequately defend the nation's vital information resources. Missouri S&T is certified by the National Security Agency (NSA) Committee on National Security Systems (CNSS) for National Standards 4011 (National Training Standard for Information Systems Security (INFOSEC) Professionals) and 4014E (Information Assurance Training Standard for Information Systems Security Officers (ISSO)). The NSA's Information Assurance Courseware Evaluation (IACE) Program implements a process to systematically assess the degree to which the courseware from commercial, government, and academic sources maps to the national standards set by CNSS. The Information Assurance & Security Officer Essentials graduate certificate program satisfies the 4011 and 4014 standards.

COMP SCI 4700 Intellectual Property of Computer Scientists
COMP SCI 5601 Security Operations & Program Management
COMP ENG 5420 Introduction to Network Security
COMP ENG 6510/Sys Eng 6322 Resilient Networks
COMP ENG 6605 Advanced Network Security

The following prerequisite courses are specifically required as part of the CNSS certification but are not part of the certificate.

COMP SCI 3800 Introduction to Operating Systems
COMP SCI 4600 Computer Communications and Networks

Information on NSA's IA Courseware Evaluation Program can be obtained at the following URL:
http://www.nsa.gov/ia/academic_outreach/iace_program/

# Ph.D. Programs

## Admission to Program

Applicants need a B.S. in engineering, physical science or math; M.S. in Systems Engineering or related field with a minimum GPA of 3.5; a minimum of three years of postgraduate work; V ≥ 155, Q ≥ 148, A ≥ 4.0. A Statement of Purpose and Three Letters of Recommendation are required for all students. A Qualifying Exam is required by the 5th semester of coursework. All requirements should be completed within an eight year period. A comprehensive exam is required near the completion of classes.

A candidate for the Ph.D. in Systems Engineering must complete the equivalent of at least three years of full-time work beyond the bachelor's degree. The content of all Ph.D. programs are individually structured by the student in consultation with and approved by the student's advisory committee. All requirements for the degree must normally be completed within an eight year period. At appropriate points in their program, Ph.D. students must pass both a qualifying examination and a comprehensive examination. Off-campus students are expected to complete all requirements listed in the Missouri University of Science and Technology Graduate Catalog (catalog.mst.edu) under the section entitled Doctor of Philosophy Degrees and follow all procedures listed under the Procedures for Ph.D. Candidates.

The total credit requirements for graduation are in general 60 credits after the successful completion of M.S. degree in Systems Engineering, or 90 credits after a B.S. degree. Actual courses taken will be determined by the candidate's committee and program of study. The student will be expected to complete all requirements listed in the Missouri S&T Graduate Catalog.

## Residency Requirements

All students are expected to follow the Missouri S&T Graduate Student Residency requirements. Off-campus students can meet the department residency requirement with the following requirements: the Qualifying Exam must be taken on campus by the 5th semester of coursework; the student will have at minimum two video conferences per month with his/her research advisor; the Ph.D. committee will include one person from the student's professional work location, the appointment committee member must have a Ph.D. and be familiar with the chosen research; the student is expected to meet with the Ph.D. committee on a regular basis with at least two meetings per semester; the Ph.D. Comprehensive Exam must be taken on campus; the student has the option of conducting research that is beneficial to the student's professional work; the Defense of Dissertation must take place on campus.

## Ph.D. Course Requirements

**Core Curriculum - 24 Credit Hours**

- SYS ENG 5101 Systems Engineering and Analysis
- SYS ENG 6102 Information Based Design
- SYS ENG 6103 Economic Analysis of Systems Engineering
- SYS ENG 6104 Systems Architecting
- SYS ENG 6105 Complex Engineering Systems Project Management
- SYS ENG 6196 Systems Engineering Capstone
- SYS ENG 6239 Smart Engineering System Design
- SYS ENG/COMP ENG 6321 Modeling Complex Systems

**Electives – 36 Credit Hours**

- Systems Eng Process Tools, Optimization & Statistics – 12 credit hours
- Research Specialization Areas – 24 credit hours

**Research – 30 Credit Hours**

## Areas of Research Specialization:

- Cyber Physical Systems
- Modeling and Simulation
- Model Based Systems Engineering
- System of Systems Architecting
- Complex Adaptive Systems
- Human System Integration
- Infrastructure Systems

## Dissertation Requirements

Students will conduct original research demonstrated by journal or referred proceedings, publications under the supervision of a doctoral advisor, and communicate their findings, write a dissertation on research conducted, and provide satisfactory defense of their dissertation in a final oral examination. Students are required to publish their work in approved journals and referred proceeding. A minimum of three articles is expected.

## Qualifying Exam

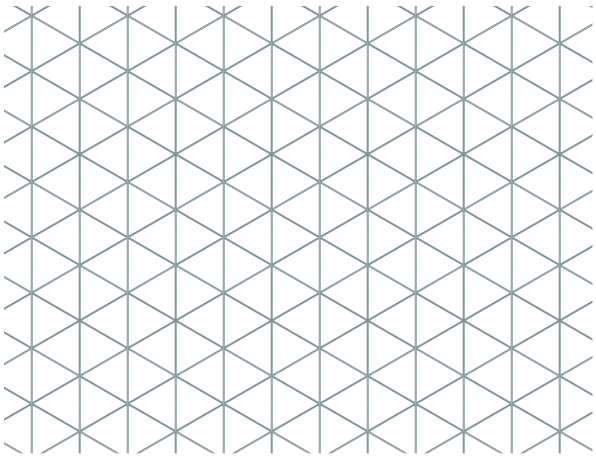
The objective of the Systems Engineering Ph.D. qualifying exam is to test the knowledge and understanding of the graduate student on systems engineering fundamentals and assess the student's level of knowledge in engineering statistics and optimization. The qualifying exam is a two-day exam consisting of written and oral parts. For more information, contact the department graduate staff. It is expected that the graduate student will have a clear understanding of the research issues in the student's area of interest, its implications in industrial applications (primarily in the industrial domain the student is working), possible impact of successful research contributions to systems engineering literature, and be able to identify up to five journals in this area. Prior to the oral exam, copies of the written exams reviews prepared by the faculty will be provided to all Engineering Management and Systems Engineering faculty for each student. The oral exam is restricted to the areas of research specialization selected by the student and will continue until there is a consensus not to ask further questions by the faculty.

## Comprehensive Exam

The student's advisory committee will administer the comprehensive examination after the student has completed the coursework for the Ph.D. program and one published refereed conference proceedings or journal paper. The examination is written and oral. Upon successful completion of the written examination, the student will be orally examined by the advisory committee.

## Dissertation

The dissertation, embodying the results of an original investigation, must be written upon a subject approved by the student's advisor.



## Ph.D. Dissertation Titles

Domain Independent Method to Assess System of Systems Meta-Architecture Using Domain Specific Fuzzy Information, ***Louis Edward Pape II, December 2015, INCOSE 2013 Doctoral Award Winner***

Multi-Level Evolutionary Algorithms for Resource Allocation Utilizing Model-Based Systems Engineering, ***Banuchander Reddy Poreddy, December 2015***

Computational Intelligence Based Complex Adaptive System-of-System Architecture Evolution Strategy, *Siddhartha Agarwal, May 2015,* ***INCOSE 2014 Doctoral Award Winner***

Detection and Recognition of RIF Devices Based on Their Unintended Electromagnetic Emission Using Stochastic and Computational Intelligence Methods, ***Shikhar Prasad Acharya, December 2014***

A Contingency Base Camp Framework Using Model Based Systems Engineering and Adaptive Agents, ***Dustin Nottage, July 2014***

Sustainability Analysis In Integrated Inventory Control And Transportation Systems, *Brian Schaefer, May 2014*

Searched Based System Architecture Development Using A Holistic Modeling Approach, ***Renzhong Wang, August 2012, INCOSE 2008 Doctoral Award Winner***

Architecture Value Mapping: Using a Linguistic Information Representation Scheme and Fuzzy Cognitive Maps as a Reasoning Mechanism for Multi-Criteria Conceptual Design Evaluation, ***Atmika Singh, December 2011***

Assessing System Architectures: The Canonical Decomposition Fuzzy Comparative Methodology, ***Jason Dauby, November 2009,*** **INCOSE 2010 Doctoral Award Winner**

Modeling Network Traffic on a Global Network-Centric System with Artificial Neural Networks, ***Douglas Keith Swift, December 2007***

Architecting System of Systems: Artificial Life Analysis of Financial Market Behavior, ***Nil Hande Kilicay-Ergin, June 2007***

MISSOURI S&T

# Participating Faculty

## ENGINEERING MANAGEMENT AND SYSTEMS ENGINEERING FACULTY

**Allada, Venkat, Ph.D., Professor**
*Engineering Management and Systems Engineering; Vice Provost of Graduate Studies*
Sustainable Product Development, Product Platform Design, Mass Customization, Product Innovation, Lean Manufacturing, Intelligent, Manufacturing Systems, Process Planning Supply Chain Management, Systems Engineering Process and Design

**Corns, Steven, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
*Associate Chair of Graduate Studies*
Computational Intelligence, Complex Systems, Bioinformatics

**Cudney, Elizabeth, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
Quality Engineering, Pattern Recognition, Healthcare Systems Engineering

**Dagli, Cihan, Ph.D., Professor**
*Engineering Management and Systems Engineering, Founder and Director of Systems Engineering Graduate Program,*
Systems Engineering and Architecting, Cyber Physical Systems and Computational Intelligence: Neural Networks – Fuzzy Logic – Evolutionary Programing

**Enke, David, Ph.D., Professor**
*Engineering Management and Systems Engineering*
Financial Engineering, Investments, Stocks, Derivatives, Portfolio Management, Financial Risk Management, Enterprise Risk Management, Financial Forecasting, Volatility Forecasting, Trading, Hedge Fund Replication, Computational Intelligence, and Artificial Intelligence

**Gosavi, Abhijit, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
Simulation-Based Optimization, Markov Decision Processes, Airline Revenue Management, Total Productive Maintenance

**Grantham, Katie, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
Risk Analysis and Mitigation, Product Design, Engineering Education

**Guardiola, Ivan, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
Stochastic Modeling, Stochastic Processes, Applied Probability and Statistics, Pattern Recognition, Linear and Nonlinear Optimization, Cross Entropy Methods, Systems Engineering Analysis and Tools

**Hodges, Sheryl, Ph.D., Assistant Teaching Professor**
*Engineering Management and Systems Engineering*
Program/Project Management, Financial Management, Organizational Management, Engineering/Construction

**Konur, Dincer, PhD., Assistant Professor**
*Engineering Management and Systems Engineering*
Operations Research and Game Theory, Supply Chain/ Operations Management, Logistics and Transportation, System of Systems Architecting

**Long, Suzanna, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
*Interim Department Chair*
Critical Infrastructure Systems, Strategic Management, Sustainable Infrastructures, Management, Supply Chain and Transportation, Systems Management, Organizational Behavior, Sociotechnical Systems Analysis

**Marley, Robert, Ph.D., Professor, Provost and Executive Vice Chancellor for Academic Affairs**
*Provost and Executive Vice Chancellor for Academic Affairs*
Human Systems Integration, Ergonomics

**Murray, Susan, Ph.D., P.E., Professor**
*Engineering Management and Systems Engineering*
*Interim Chair for the Department of Psychological Science*
Human Factors, Human Systems Interactions, Industrial Safety, Fatigue Risk Management, and Engineering Education

**Qin, Ruwen, Ph.D., Assistant Professor**
*Engineering Management and Systems Engineering*
Real Options, Financial Engineering, Workforce Engineering, Data-driven Decision Modeling

**Raper, Stephen, Ph.D., Associate Professor**
*Engineering Management and Systems Engineering*
*Associate Chair of Undergraduate Studies*
Packaging Systems, Engineering Management, Undergraduate Education

**Schuman, Joan, Ph.D., Assistant Teaching Professor**
*Engineering Management and Systems Engineering*
Engineering Education, Project Management

**Spurlock, David, Ph.D., Lecturer**
*Engineering Management and Systems Engineering*
General Management

**Sun, Zeyi, Ph.D., Assistant Professor**
*Engineering Management and Systems Engineering*
Energy efficiency management of manufacturing systems, Electricity demand response of manufacturing systems, Systems modeling of cellulosic biofuel manufacturing, Energy modeling and control in additive manufacturing, Intelligent maintenance of manufacturing systems

# Affiliated Faculty

**Bahrami, Ali, Ph.D., Adjunct**
*Engineering Management and Systems Engineering, The Boeing Company, Technical Fellow*

**Carson, Ron, Ph.D., Adjunct**
*Engineering Management and Systems Engineering, The Boeing Company (retired), Technical Fellow, INCOSE Fellow*

**Chandrashekhara, K, Ph.D., Curators' Professor**
*Mechanical and Aerospace Engineering*

**Do, Quoc, Ph.D**.
*President, System Engineering Societies of Australia, Frazer-Nash Consultancy Ltd, Adelaide, Australia*

**Hoffman, Gerald, Ph.D., Adjunct**
*Engineering Management and Systems Engineering, Hallmark Cards*

**Pape, Louis Edward, PhD. Adjunct**
*Engineering Management and Systems Engineering The Boeing Company, Associate Technical Fellow*

**Sarangapani, Jagannathan, Ph.D., Professor**
*Electrical and Computer Engineering*

**Wunsch II, Donald, Ph.D., Mary Finley**
*Missouri Distinguished Professor*
*Electrical and Computer Engineering*

**Yildirim, Gonca, Ph.D., Adjunct**
*Engineering Management and Systems Engineering, Çankaya University, Ankara, Turkey*

## Department Contact Information

**Dr. Cihan Dagli**
*Founder and Director of Systems Engineering Graduate Program/Student Advisor*
Phone: 573-647-9125; Email: dagli@mst.edu

**Jessica Satterfield and Sarah Johnson**
*Engineering Management and Systems Engineering Graduate Student Services*
Phone: 573-341-4572
Email: syseng@mst.edu
Web: emse.mst.edu

**Systems Engineering Department Mailing Address:**
*223 Engineering Management*
600 West 14th St., Rolla, MO 65409-0370

## Admissions and Enrollment Information

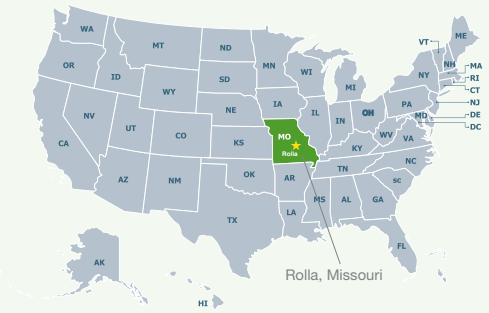
**Vicki Gibbons**
*Senior Assistant Director*
*Student Support Services*
Phone: 573-341-4892; Toll Free: 1-877-678-1870
Fax: 573-202-2396
Email vgibbons@mst.edu or global@mst.edu
Web: distance.mst.edu
216 Centennial Hall, 300 West 12th St.
Rolla MO 65409-1560

## Technical Information

**Video Communications Center**
Phone: 573-341-6490; Fax: 573-341-6993
Email: vcchelp@mst.edu; Web: vcc.mst.edu
G-8 Wilson Library, 400 W 14th St.,
Rolla, MO 65409-0330

MISSOURI S&T

# AT A GLANCE




## Campus

Founded in 1870 as Missouri School of Mines (MSM)

Became University of Missouri-Rolla (UMR) in 1964 and Missouri University of Science and Technology (Missouri S&T) in 2008

First U.S. university to attain ISO (International Organization for Standardization) 14001 certification in environmental management

## Location

284-acre campus located in Rolla, Missouri, a town of 18,000 in the heart of the Ozarks

For Rolla area information visit rollachamber.org

## Enrollment

More than 8,800 total students (6,900+ undergraduates; 1,900+ graduates)

Students from 50 states and 60 foreign countries

## Faculty

Approximately 400 full-time faculty

99% of full-time tenured and tenure-track faculty have PhDs, or the highest degree in their field

Individual faculty advising

## Research

More than 25 research centers, labs and institutes foster interdisciplinary research

More than $30 million in externally funded research expenditures for FY2016

World leaders in data security, transportation, infrastructure, energy, manufacturing and e-commerce research

Missouri S&T named state's only National Center of Academic Excellence in Information Assurance and Cyber Defense Research

Nearly half of S&T graduates complete a research project

## Academic Calendar

Two primary semesters and one summer semester
Fall (Aug-Dec); Spring (Jan-May); and Summer (June-July)

## Career Success

Average reported starting salaries at graduation for S&T graduates was more than $76,600

Career Center ranks 15th in the nation
*(The Princeton Review)*