Systems Engineering (MS/PhD)

Distance graduate degrees & certificate programs

2014-2015
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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 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 more than 45 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, IIE, 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 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.
Points of distinction
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: Model Based Engineering, Systems Architecting, Computational Intelligence, Human System Integration, and Infrastructure Systems.

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 current 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 465 Boeing students have graduated from the systems engineering program. Our faculty include two of the 71 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 systems engineers face in real programs, along with systems engineering tools that are available 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 systems engineering Ph.D. students.

Complex Adaptive Systems Conference. (formerly ANNIE) For the past twenty-three 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.

Missouri S&T’s National Science Foundation Industry/University Cooperative Research Center (NSF I/UTRC) 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/UTRC is one of the research units of the Systems Engineering Graduate Program.

Energy Research & Development Center. The Energy Research and 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.

Missouri S&T houses the Center for Aerospace Technologies (CAMT). This center is a collaboration of Missouri S&T, Boeing Phantom Works and the Air Force Research Laboratory. The mission of CAMT is to serve as a center of excellence in 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.

Missouri S&T’s 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, such as electric power, and infrastructure management.

A top 20 STEM Research University. (Academic Analytics) “STEM” stands for “science, technology, engineering and mathematics.”

Missouri S&T’s state-of-the-art Video Communication 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 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.
The Master’s Degree Program requires the successful completion of six core courses and four approved specialization track 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 of the university being attended, 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. The certificate program may be followed by six to eight 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
- Undergraduate GPA regular status 2.75 cumulative
- 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
M.S. in Systems Engineering

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

A minimum of 30 credit hours 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 credit hours 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 Department, if necessary. More details about requirements can be found in the university catalog, and are available from the EMSE Department upon request. Details about the program can also be found at http://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 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 will be admitted to the M.S. program in Systems Engineering without taking the GRE. 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.
Systems Engineering (M.S.)
Core Courses

Systems Architecting and Analysis

SYS ENG 5101 System Engineering and Analysis I
(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 Systems Engineering Analysis II
(LEC 3.0)
This course uses customized case studies based on team projects from prior courses. Topics covered include physical and functional analysis, analysis and traceability of requirements and specifications, verification and validation, optimization, simulation, and trade studies. Prerequisite: Sys Eng 5101.

SYS ENG 6104 Systems Architecting (LEC 3.0)
The objective of the course is to provide the basic tools and concepts of architecting complex engineering systems. Systems thinking, ambiguity in system architecting, search as an architecting process, SysML and DoDAF Architecting Framework, System of Systems and Network-Centric Architectures. Prerequisite: Sys Eng 6102; can be taken concurrently with Sys Eng 6102 with consent of instructor.

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: Sys Eng 5101; can be taken concurrently with Sys Eng 5101 with consent of instructor.

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: Sys Eng 6102; can be taken concurrently with Sys Eng 6102 with consent of instructor.

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 and 6104; can be taken concurrently with Sys Eng 6104, with consent of instructor.

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.
Graduate Certificates
For Systems Engineering, Network Centric Systems
Big Data Management, 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, 6104, and 6103 with a grade of “B” or better in each course taken.

Core Courses:
SYS ENG 5101 Systems Engineering and Analysis I
SYS ENG 6102 Systems Engineering Analysis II
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 Courses:
SYS ENG 6321/COMP ENG 6410
Network Centric Systems (LEC 3.0)

Network-centric systems comprises a diverse category of complex systems with the primary purpose is providing network-type services.

Elective Courses:
(Select three courses from the following specialization tracks)

Communications Engineering
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 Digital Network Design (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, multicaeting, switching, and internetworking. A modeling tool is used for network design and simulation. Prerequisite: Comp Eng 3550 or computer hardware competency.

COMP ENG 5420 Trustworthy, Survivable Computer Networks (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.

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.
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. Prerequisite: Comp Sci 5150 or programming competency.

And select one of the following:
- SYS ENG 5212/ELEC ENG 5370 Introduction To Neural Networks & Applications (LEC 3.0)
  Introduction to artificial neural network architectures, adaline, madaline, back propagation, BAM, and Hopfield memory, counter propagation networks, self-organizing maps, adaptive resonance theory, are the topics covered. Students experiment with the use of artificial neural networks in engineering through semester projects. Prerequisites: Math 3304 or 3329; 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 Critic Designs (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 Data Mining & Knowledge Discovery (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 & Applications
(Course description is provided on page 7, second column)

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

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)
Introduction to systems modeling with software tools, focusing on distributed computing systems. Topics covered include object oriented engineering, network communication principles, Unified Modeling Language (UML), distributed system algorithms and protocols for system operability.

SYS ENG 6542 Model Based Systems Engineering (LEC 3.0)
This course covers the use of models to represent systems and the underlying system elements, components, etc. The systems modeling language (SysML) is examine to show and how it can be used to shift systems engineering from a document centric paradigm to one that is model centric. Topics also include executable systems architectures, model repository, integration of models and information, and use of Model Based Systems Engineering in a distributed system. Prerequisite: Sys Eng 6541 or UML experience.

SYS ENG 6239 Smart Engineering Systems Design (LEC 3.0)
This course covers the emerging approaches for designing of smart engineering systems architectures for complex systems through evolutionary acquisition, namely; adaptive architecture generation for system of systems, complexity theory, evolutionary programming, fuzzy logic, collaborative behavior, artificial life, and chaos. Prerequisite: Sys Eng 5212 or 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.
Big Data Management and Analytics

dce.mst.edu/credit/certificates/bigdatamanagementandanalytics/

This is a specialized graduate certificate program to teach practicing computing professionals and graduate students the skills that are necessary for the use and development of big data management, big data analytics, data mining, cloud computing, and business intelligence.

The following courses are required:
- COMP SCI 5001 Introduction to Data Mining
- COMP SCI 6001 Cloud Computing

Choose one course from the following:
- IST 3001 Introduction to Big Data Analytics
- COMP ENG 4330/ELEC ENG 6340/SYS ENG 6214/COMP SCI 6300/STAT 6239 Clustering Algorithms
- ERP 5410 Use of Business Intelligence
- COMP SCI 6301 Web Data Management and XML
- COMP SCI 6302 Heterogeneous and Mobile Databases

Choose one course from the following:
- COMP SCI 5300 Database Systems
- IST 6444 Essentials of Data Warehouses
- COMP SCI 6402 Advanced Topics in Data Mining
- STAT 5814 Applied Time Series Analysis

Note: There is overlap between the course offerings for this graduate certificate and the Big Data and Management and Security certificate. No course can be used to satisfy the requirements for more than one graduate certificate.

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 on page 8, second column.)

- 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 covers all the activities involved in discovering, analyzing, specifying and managing software requirements for a software system from multiple perspectives. Students will study how to elicit, analyze, specify, validate, and manage software requirements using advanced software requirements engineering methods. Prerequisite: Comp Sci 3100.
Ph.D. Course Requirements

Core Curriculum - 24 Credit Hours
- SYS ENG 5101 Systems Engineering and Analysis I
- SYS ENG 6102 Systems Engineering Analysis II
- 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/COMP ENG 6321 Network-Centric Systems Reliability & Security

Electives – 36 Credit Hours
- COMP ENG 5420 Trustworthy, Survivable Computer Networks
- COMP ENG 6510/Sys Eng 6322 Network-Centric Systems Reliability & Security

Research – 30 Credit Hours
- 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. Course Requirements

Core Curriculum - 24 Credit Hours
- SYS ENG 5101 Systems Engineering and Analysis I
- SYS ENG 6102 Systems Engineering Analysis II
- 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/COMP ENG 6321 Network-Centric Systems

Electives – 36 Credit Hours
- Systems Eng Process Tools, Optimization & Statistics – 12 credit hours
- Research Specialization Areas – 24 credit hours

Research – 30 Credit Hours

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; GRE scores of 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

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

Systems Engineering
Ph.D. Program

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; GRE scores of 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 his or her 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 two-year 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 student is expected to be on campus a minimum of 16 days per year, visits may be spread over four campus visits; 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.

**Dissertation Requirements**
Students will conduct original research demonstrated by journal or refereed 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. The dissertation, embodying the results of an original investigation, must be written upon a subject approved by the student’s advisor. Students also are required to attend Sys Eng 6010 Seminar every fall and spring semester during their study. These credits may be included in research credit requirements. Students are required to publish their work in approved journals and refereed proceedings. 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.

**Recent Ph.D. Dissertation Titles**
- 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
- 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
Areas of Research Specialization
(and Selected Research Topics)

Modeling and Simulation
- Developing Mathematical Models for Project Risk Management
- Distributed System Modeling
- Modeling and Simulation for Embedded Systems
- Complex Systems Modeling

Systems Engineering Processes and Design
- Simulation and Mathematical Optimization of Engineering Systems
- Performance and Cost Optimization of Embedded Systems
- Integration of Ontologies into System Engineering

System of Systems Architecting
- System of Systems
- Architecture Frameworks
- Executable Architectures
- Smart Systems Engineering
- Design for Flexibility
- System Architecture Evaluation
- End-to-End System Security
- High Speed Networks
- Wireless Networks
- Wireless Ad Hoc and Sensor Networks
- Information Assurance
- Vulnerability Assessments
- Reliability Analysis
- Network-Centric Collaborative Design
- Sustainable Development of Network Centric Infrastructure Systems

Computational Intelligence
- Neural Networks, Fuzzy Logic Evolutionary Programming
- Swarm Optimization for Intelligent Systems
- Approximate Dynamic Programming and Reinforcement Learning Application
- Data Mining
- Time Series Forecasting
- Clustering Algorithms
- Computational Intelligence in Game Theory

Human System Integration
- Human-Centered Complex Systems Design
- Modeling of Human Performance
- Integrating Human Components to System of Systems

Infrastructure Systems
- Health Monitoring of Infrastructure Systems
- Behavior of Infrastructure Systems Under Extreme Conditions
- Transportation Infrastructure Architecting
- Energy Infrastructure Systems
  - Smart Grid
  - Capacity Modeling and Analysis
  - Renewable Systems
  - Energy Reliability
- Structures

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Faculty

Allada, Venkat, Ph.D., Professor

Corns, Steven, Ph.D., Associate Professor
Engineering Management and Systems Engineering, Systems Engineering, Evolutionary Computation, System Modeling and Optimization, Bioinformatics and Computational Biology

Cudney, Elizabeth, Ph.D., Associate Professor
Engineering Management and Systems Engineering, Quality, Six Sigma, Robust Engineering, Lean Enterprise

Dagli, Cihan, Ph.D., Professor

Enke, David, Ph.D., Professor
Engineering Management and Systems Engineering, Department Chair, Financial Forecasting, Financial Engineering, Investments and Derivatives, Computational Intelligence, Computational Finance, Financial Risk Management

Gosavi, Abhijit, Ph.D., Associate Professor
Engineering Management and Systems Engineering, Lean Manufacturing, Supply Chain Management, Revenue Management, Simulation-Optimization

Grantham, Katie, Ph.D., Associate Professor

Guaddiola, Ivan, Ph.D., Associate Professor

Konur, Dincer, Ph.D., Assistant Professor

Long, Suzanna, Ph.D., Associate Professor
Engineering Management and Systems Engineering, Strategic Management, Change Management, Business Logistics and Marketing

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

Murray, Susan, Ph.D., P.E., Professor

Qin, Ruwen, Ph.D., Assistant Professor
Engineering Management and Systems Engineering, Real Options, Financial Engineering, and Manufacturing and Service Operations

Raper, Stephen, Ph.D., Associate Professor

Schuman, Joan, Ph.D., Assistant Teaching Professor
Project Management and Engineering Economics

Smith, Brian, Ph.D., Assistant Professor
Engineering Management and Systems Engineering Health Care, Supply Chain, Logistics

Affiliated Faculty

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

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

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

Bahrami, Ali, Ph.D., Adjunct

Cassone, Deandra, Ph.D., Adjunct
Engineering Management and Systems Engineering, Sprint

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

Cimtalay, Jelcuk, Ph.D., Adjunct
Senior Research Engineering Aerospace Systems Design Laboratory, Georgia Institute of Technology

Ferris, Timothy, Ph.D., Adjunct
Engineering Management and Systems Engineering, Defense and Systems Institute, University of South Australia
“I would definitely recommend distance education from Missouri S&T. The flexibility in the plan of study, the wide range of courses offered via distance, and the technology used for content delivery makes Missouri S&T an obvious choice.”

Jason Dauby (PhD SysEng)

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 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, Mo., a town of 18,000 in the heart of the Ozarks
- For Rolla area information visit www.rollanet.org

Enrollment
- More than 8,600 total students (6,600+ undergraduates; 2,000+ graduates)
- Students from 50 states and 65 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 $45 million in externally funded research expenditures
- World leaders in data security, transportation, infrastructure, energy, manufacturing and e-commerce 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 starting salary for graduates is more than $65,500
  (Systems engineering graduates make an average starting salary of $70,000)
- No. 2 for public university for starting salaries and top 13 in the nation (PayScale)
- Career Center ranks 17th in the nation (The Princeton Review)

1. Academic Quality
   A top 20 STEM Research University (Academic Analytics) STEM refers to science, technology, engineering and mathematics

2. World-Class Faculty
   Faculty are world leaders in electrical and cyber systems, energy, the environment, civil infrastructure, manufacturing and materials

3. Nationally Ranked Online Graduate Programs
   Missouri S&T has 15 online master’s programs ranked among the best in the country. Programs include 11 engineering disciplines, computer science, IST and MBA (U.S News and World Report, 2014)

4. Comprehensive Educational Programs
   15 accredited undergraduate engineering programs — more than MIT, Purdue, Georgia Tech or Virginia Tech
   17 master’s programs and more than 45 graduate certificate programs offered through distance education - for an Education that fits
   One of only a handful of universities to offer graduate programs in systems engineering.

5. Return on Investment
   No. 1 “Best Investment” among public universities for out-of-state students (Newsweek, August 2012)