SYSTEMS ENGINEERING

Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems by defining customer needs and required functionality early in the development cycle. Systems engineers are responsible for the design and management of complex systems guided by systems requirements. There is a growing need for engineers who are concerned with the whole system and can take an interdisciplinary and top down approach. Systems engineers need to be problem definers, not just problem solvers, and be involved with a system through its life cycle, from development through production, deployment, training support, operation, and disposal.

Graduate programs leading to the M.S. and Ph.D. degrees are offered in systems engineering. The graduate program builds on sound engineering undergraduate education, experience, and maintains engineering specialization diversity in its graduates.

Systems engineering research is supported by interdisciplinary research and collaboration. Research areas include: model based engineering, systems architecting, modeling and simulation, complex adaptive systems, computational intelligence, human system integration and infrastructure systems. The systems engineering graduate program, with over 640 graduates since 2000, contributes to the research challenges of systems engineering imposed by today's complex, adaptive, distributed, cooperative and dynamically changing engineering systems. As one of the leading systems engineering program in the nation, Missouri S&T is the only university in the world to have four INCOSE (International Council on Systems Engineering) Stevens Doctoral Award recipients. Systems engineering faculty members are active leaders in systems engineering and architecting research, conferences and other professional activities and associations.

Requirements for Completion

Students following their approved program of study will be assured of graduation upon maintenance of good academic standing. A minimum of 30 hours of course work (non-thesis) or 36 hours of course work (thesis) 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 10 hours of “C” or “F” results in dismissal from the program. A maximum of nine hours of course work for M.S. degrees may be transferred from universities outside the University of Missouri System. Such credits for transfer must have been registered as graduate courses when they were taken. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. 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.

Departmental Laboratories

The department has several "hands on" laboratories that have both a research and teaching focus. Each of our labs is directed by faculty members that work closely with students to enhance their learning experience. The description below gives a brief introduction that will help you understand the purpose of each lab.

Smart Engineering Systems Lab (SESL)

The department established the Smart Engineering Systems Lab (SESL) to develop approaches in building complex systems that can adapt in the environments in which they operate. The term "smart" in the context indicates physical systems that can interact with their environment and adapt to changes both in space and time by their ability to manipulate the environment through self-awareness and perceived models of the world based on both quantitative and qualitative information. The emerging fields of cyber physical systems, deep neural networks, fuzzy logic, evolutionary programming, and complex adaptive systems provide essential tools for designing such systems.

The focus of the SESL is in developing smart engineering architectures that integrate and/or enhance the current and future technologies necessary for developing smart engineering systems while illustrating the real life applications of these architectures. The smart engineering systems design and operations cut across a diversity of disciplines, namely manufacturing, electrical, computer, and mechanical, biomedical, civil and other related fields such as applied mathematics, cognitive sciences, biology and medicine. Current research is on developing new models and tools for building complex systems architectures that are intelligent, modular, and adaptive.

Design Engineering Center (DEC)

The center is one of the outreach arms of the engineering management and systems engineering department. The focus is on research and service activities in support of the educational goals of the department through externally funded projects. Current areas of research include total quality management, concurrent engineering, Taguchi Methods®, quality engineering, the product development process, and design optimization.

Laboratory for Investment and Financial Engineering

The goal of the Laboratory for Investment and Financial Engineering is to develop techniques and computational tools for increasing investment and capital return while managing and reducing financial risk. This involves research into stocks and financial derivatives (options, futures, forwards, and swaps), financial risk and uncertainty, financial forecasting, market efficiency and behavioral finance, fundamental and technical analysis, equity valuation, real options, and engineering economics. In cooperation with the Smart Engineering Systems Lab, research in the lab may also involve the use of smart and intelligent systems, such as neural networks, fuzzy logic, genetic and evolutionary algorithms, expert systems, intelligent agents, artificial life, chaos and fractals, and dynamic and complex systems. Data mining, principal component analysis and various other forms of applied statistics are also used. Members of the lab have access to financial data and various financial modeling software packages.

The Virtual and Augmented Reality Systems Engineering Lab (VASEL)

The Virtual and Augmented Reality Systems Engineering Lab (VASEL) has been established to complement ongoing and future research work within the department, the S&T campus and across the UM system. The research conducted in this lab will address current and future challenges faced at the boundaries and interfaces of science, technology and engineering research that are essential for the next level of scientific advances to address societal needs. These challenges are found at the nexus of various domains and require experts from all backgrounds of science and engineering to facilitate research leading to the emergence

of new disciplines and the generation of knowledge, particularly in the areas of complex systems design and development.

The focus of the VASEL is the research and development of techniques and platforms that are essential to understanding the complementary and competitive teaming of humans with natural and engineered systems. This includes design and evaluation of human response to extreme events such as earthquakes and floods which informs our understanding of developing protocols to address these natural events. Research involving human response to manufactured events such as fires, shootings and even cyber-attacks similarly will lead to engineered strategies facilitated by the virtual environments used as experimental platforms.

Additional Information

For additional information you can call our main department phone at 573-341-4572 or you can visit our web page at http://emse.mst.edu/.

Master of Science Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: Regular status: 3.0 cumulative
- Graduate Record Exam (GRE): All students must submit current GRE scores. Students successfully completing one of the department's graduate certificates with a grade of "B" or better in all the certificate courses can be admitted without the GRE.
  - Regular status: V≥ 155, Q≥ 148, A≥ 4.0
  - Condition: Student must earn "B" or better in each of first four graduate (5000 or 6000 level) classes after conditional admission.
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study. Regular status: 92
- Statement of Purpose: All applicants must submit a statement of purpose.
- Financial Support: Students in conditional status are not eligible for financial support from the department.
- Three reference letters

The M.S. degree program is offered on the Rolla campus and several locations including the Missouri S&T Global - St. Louis, and by distance education throughout the United States and selected international locations. Distance course lectures are archived upon completion of the lecture and all lectures are available to students through streaming video during the semester for review. These courses can be reached from anywhere at any time. It is feasible to obtain a Missouri S&T non-thesis M.S. degree regardless of your location.

The M.S. non-thesis program requires completion of at least 10 three-credit hour courses approved by the academic advisor. The M.S. with thesis option requires 36 credit hours including the thesis. All students are required to take the following:

CORE Courses

SYS ENG 5101	System Engineering and Analysis	3
SYS ENG 6102	Information Based Design	3
SYS ENG 6103	Systems Life Cycle Costing	3
SYS ENG 6104	Systems Architecting	3
SYS ENG 6196	Systems Engineering Capstone	3
SYS ENG 6542	Model Based Systems Engineering	3

Specialization Courses

Specialization courses provides students with the ability to address his/her technology needs in the context of the overall Systems Engineering program. These graduate courses can be selected from engineering or the physical science department as long as they are approved by the program director.

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

Doctor of Philosophy Admission Standards

- B.S. in engineering, or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: M.S. GPA = 3.5
- Graduate Record Exam (GRE): All students must submit current GRE scores. V≥ 155, Q≥ 148, A≥ 4.0
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study. Regular status: 92
- Statement of Purpose: All applicants must submit a statement of purpose.
- Three reference letters

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 Exam and Comprehensive Exam. Off-campus students are expected to complete all requirements listed in the Missouri S&T Graduate Catalog under the section entitled Doctor of Philosophy Degree and follow all procedures listed under the Procedures for Ph.D. Candidates.

The total credit requirements for graduation are a minimum of 54 credit hours after the successful completion of M.S. degree in systems engineering. Actual courses taken will be determined by the candidate's committee and his/her plan of study. The student is expected to complete all requirements.

For Off-Campus Students

The qualifying exam must be taken on campus within the first 5 semesters of enrollment; the student will have at minimum one virtual conference per month with his/her research advisor; 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; and the defense of dissertation must take place on campus.

Major Requirements

After B.S. degree in Engineering

Core Curriculum		**24**
SYS ENG 6412	Mathematical Programming	3
SYS ENG 6110	Optimization under Uncertainty	3
SYS ENG 6101	Advanced Research Methodology in Engineering Management	3
SYS ENG 6104	Systems Architecting	3
SYS ENG 5101	System Engineering and Analysis	3
SYS ENG 6542	Model Based Systems Engineering	3
SYS ENG 6321	Modeling Complex Systems	3
SYS ENG 6239	Smart Engineering System Design	3
Research		**30**
SYS ENG 6099	Research	1-15
Electives		**36**
Systems Eng Process Tools, Optimization & Statics - 12 credit hours		
Research Specialization Areas - 24 credit hours		

Requirements for Dissertation

Students will conduct original research demonstrated by journal or referred proceedings, publication 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 will be required to sign up for one hour of SYS ENG 6099 under their research advisor. Students are required to publish their work in approved journals and referred 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 student's research capability.

It is expected that the graduate student has 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 research and literature. For more information, contact the department graduate staff.

Comprehensive Exam

The student's advisory committee will administer the comprehensive examination after the student has completed seventy-five percent of the coursework for the Ph.D. program and one published refereed conference proceeding 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 mutually agreed upon between the student and the advisor.

Research Areas

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

Graduate Certificate Programs

This program is designed to appeal to working professionals. Certificate courses taken for graduate credit can be counted in the M.S. degree once accepted into the M.S. degree. If the four-course sequence is completed with a grade of "B" or better in each of the courses taken, they can apply to be admitted to the M.S. program in systems engineering with all application requirements waived. The certificate program may be followed by six to eight additional 3 credit hour courses to complete the M.S. degree. The certificate program is open to all persons holding a B.S., M.S., or Ph.D. degree in engineering or a physical science and who have a minimum of 12-months of professional employment experience or are currently accepted into a graduate degree program at Missouri S&T.

Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics or Chemistry, Engineering Economy
- GPA: Regular status: 2.75 cumulative
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study. Regular status: 92

Once admitted to the program, the student must take the four designated courses as given below. In order to receive a graduate certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses.

Computational Intelligence Certificate

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 towards 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
Select one of the following:	
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications
COMP SCI 5400	Introduction To Artificial Intelligence
COMP SCI 5401	Evolutionary Computing
Select two of the following not taken as a core course:	
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications
ELEC ENG 5320	Neural Networks Control and Applications
COMP SCI 5400	Introduction To Artificial Intelligence
COMP SCI 5401	Evolutionary Computing
COMP SCI 6400	Advanced Topics In Artificial Intelligence
COMP SCI 6401	Advanced Evolutionary Computing
SYS ENG 6213	Deep Learning and Advanced Neural Networks

SYS ENG 6214/ COMP ENG 6330/ ELEC ENG 6340/ STAT 6239	Clustering Algorithms
SYS ENG 6215/ COMP ENG 6320/ ELEC ENG 6360	Adaptive Dynamic Programming
SYS ENG 6216/ COMP ENG 6302/ COMP SCI 6402	Advanced Topics in Data Mining
COMP ENG 6310/ ENG MGT 6410/ COMP SCI 6202/ MECH ENG 6447/ AERO ENG 6447	Markov Decision Processes

Cyber Physical Systems Graduate Certificate

Cyber Physical Systems with different levels of implementation that entail complex logic with many levels of reasoning in intricate arrangement, organized by web of connections and demonstrating self-driven adaptability are emerging. They will impact manufacturing industry, defense, healthcare, energy, transportation, emergency response, agriculture and society overall.The graduate certificate in Cyber Physical systems is a joint effort between computer engineering and systems engineering to provide practicing engineers with the necessary skills to develop and design the operation of complex adaptive systems. These four courses count towards a M.S. degree in systems engineering or computer engineering and they address the intersection between computer engineering, systems engineering, and architecting. The requirements are the successful completion of two core courses and two elective courses from the list below. A grade of "B" or better is required in each course before the student is eligible for the master of science program.

Core Course:

SYS ENG 6321/ COMP ENG 6410	Modeling Complex Systems
COMP ENG 5410	Introduction to Computer Communication Networks
Elective Courses (Select two courses):	
COMP ENG 5420	Introduction to Network Security
COMP ENG 5430/ SYS ENG 5323	Wireless Networks
COMP ENG 5510	Fault-Tolerant Digital Systems
SYS ENG 6322/ COMP ENG 6510	Resilient Networks
COMP ENG 6420/ SYS ENG 6324	Wireless Ad hoc and Sensor Networks
COMP ENG 6430	High Speed Networks
COMP ENG 6440/ COMP SCI 6602	Network Performance Analysis
COMP SCI 6600	Formal Methods in Computer Security
COMP SCI 6604	Mobile, IoT and Sensor Computing

Financial Engineering

The financial engineering certificate program aims to equip students with a set of tools that will help them meet the standards of the Global Association of Risk Professionals (GARP) and the Professional Risk Managers' International Association (PRMIA) certifications. While being separate organizations, both GARP and PRMIA have become the standards in financial engineering and financial risk management, due to their similar knowledge of requirements for certification.

Certificate topics will help prepare students to take the GARP Financial Risk Managers (FRM) exam and/or the PRMIA Professional Risk Managers (PRM) exam. Both exams are set around topics in financial theory, financial markets and financial instruments, market risk measures, quantitative analysis, mathematical foundations of risk management, financial derivatives for risk reduction, risk management best practices, operational risk, market risk, credit risk, case studies, ethics, and governance. The certificate courses will provide a strong foundation in these areas.

Students will be responsible for prerequisite knowledge as determined by course instructors and are expected to have taken ENG MGT 5210 Economic Decision Analysis, ENG MGT 5202 Financial Decision Analysis, SYS ENG 6103 Systems Life Cycle Costing, or an equivalent introduction to finance and/or engineering economics course, as a prerequisite to the certificate program. To complete the certificate, students must complete any four of the five certificate courses.

ENG MGT 6212	Investment
ENG MGT 6213	Financial Engineering
SYS ENG 5212	Introduction to Neural Networks and Applications
ENG MGT 5212	Intelligent Investing
ENG MGT 6211	Advanced Financial Management

Model Based Systems Engineering Certificate

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 usability of model resources, and acquire necessary skills for simulating the designed systems.

SYS ENG 6110	Optimization under Uncertainty
SYS ENG 6239	Smart Engineering System Design
SYS ENG 6412	Mathematical Programming
SYS ENG 6542	Model Based Systems Engineering

Systems Engineering Graduate Certificate

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.

SYS ENG 5101	System Engineering and Analysis
SYS ENG 6102	Information Based Design

SYS ENG 6103	Systems Life Cycle Costing
SYS ENG 6104	Systems Architecting

Upon successful completion of the four courses as described above, students will be awarded certification. The student must complete the four courses with a grade of "B" or better in each course. Students may apply to the M.S. program with the completion of the certificate.

Venkat Allada, Professor
PHD University of Cincinnati
Sustainable produce development, product platform design, mass customization, product innovation, lean manufacturing, intelligent manufacturing systems, process planning supply chain management, systems engineering process and design.

Casey Canfield, Assistant Professor
PHD Carneige Mellon University
Human Systems Integration, Human Factors, Automation, Energy Systems, Smart Cities, Organizational Behavior, Decision Science, Risk Analysis, Risk Communication, Data Visualization, Policy Analysis, Behavioral Interventions, Program Evaluation, Implementation Science, Stakeholder Engagement.

K Chandrashekhara, Curators Distinguished Professor
PHD Virginia Polytechnic Institute
Structures and Composite Materials.

Steven M. Corns, Associate Professor
PHD Iowa State University
Associate Chair of Graduate Studies. Computational Intelligence, Complex Systems, Bioinformatics, Infrastructure Systems Modeling, Autonomous Systems.

Cihan H Dagli, Professor
PHD University of Birmingham, UK
Systems Architecting and Engineering, Cyber Physical Systems, Machine Learning, Deep Learning, Computational Intelligence. INCOSE Fellow, IISE, IFPR Fellow.

David Enke, Professor
PHD University of Missouri-Rolla
Investments, Derivatives, Options and Futures, Financial Forecasting, Trading Strategies, Hedge Funds, Endowment Investing, Financial Risk Management, Engineering Economy, Computational Finance, Computational Intelligence, Neural Networks.

Abhijit Gosavi, Associate Professor
PHD University of South Florida
Lean manufacturing, supply chain management, revenue management, simulation-optimization.

Katie Grantham, Associate Professor
PHD University of Missouri-Rolla

Sheryl Hodges, Associate Teaching Professor[1]
DEng Louisiana Tech Univeristy
Program/Project Management, Financial Management, Organizational Management, Engineering/Construction.

Benjamin Kwasa, Assistant Professor
PHD Iowa State University
Organization Design in the Design of Complex Systems, Unmanned Aerial Systems Integration, Value-Driven Design, Multidisciplinary Design Optimization, Heuristic Optimization, Systems Design, Systems Engineering, Preference Formulation and Communication, Risk Simulation in Design and Modeling, Engineering Education, Meta-Modeling, Decision Analysis, Systems Requirements Development.

Jinling Liu, Assistant Professor
PHD The Pennsylvania State University
Artificial Intelligence, Biomedical Informatics, Precision Medicine, Big Data Analytics, Systems Biology, Immunology, Causal Inference, Multi-omics data.

Suzanna K. Long, Professor[1]
PHD University of Missouri-Rolla
Critical Infrastructure Systems, Strategic Management, Sustainable Infrastructures, Management, Supply Chain and Transportation, Systems Management, Organizational Behavior, Sociotechnical Systems Analysis.

Robert Marley, Robert B. Koplar Professor
PHD Wichita State University
Human System Integration, Ergonomics.

Stephen A Raper, Associate Professor
PHD University of Missouri-Rolla
Packaging engineering, operations, productivity, total quality management, packaging systems design, environmental aspects of packaging and statistical process control.

Jagannathan Sarangapani, Professor
PHD University of Texas-Arlington
Adaptive Control, Wireless Networks.

Joan Barker Schuman, Associate Teaching Professor
PHD University of Southern Mississippi
Project Management and Engineering Economics.

David G Spurlock, Associate Teaching Professor
PHD University of Illinois Urbana
General Management.

Donald C Wunsch II, Professor[1]
PHD University of Washington
Adaptive critic designs, neural networks, fuzzy systems, surety, nonlinear adaptive control, intelligent agents, applications.

SYS ENG 5000 Special Problems (IND 1.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

SYS ENG 5001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

SYS ENG 5040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comphrehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

SYS ENG 5099 Research (IND 1.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

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 Standing.

SYS ENG 5105 Project Management (LEC 3.0)
Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisites: Graduate standing. (Co-listed with Eng Mgt 5320).

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: Graduate Standing. (Co-listed with Elec Eng 5810 and Comp Eng 5310).

SYS ENG 5212 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. (Co-listed with Elec Eng 5370).

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 adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Comp Eng 5430 and Elec Eng 5430).

SYS ENG 6000 Special Problems (IND 1.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

SYS ENG 6001 Special Topics (LEC 1.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

SYS ENG 6010 Seminar (RSD 0.0-6.0)
Discussion of current topics.

SYS ENG 6040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comphrehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

SYS ENG 6050 Continuous Registration (IND 1.0)
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from campus must continue to enroll for at least one credit hour each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

SYS ENG 6099 Research (IND 1.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

SYS ENG 6101 Advanced Research Methodology in Engineering Management (LEC 3.0)
An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing. (Co-list with Eng Mgt 6101).

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. Prerequisites: Graduate Standing.

SYS ENG 6103 Systems Life Cycle Costing (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. Prerequisites: 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. Prerequisites: 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. Prerequisites: Graduate Standing.

SYS ENG 6110 Optimization under Uncertainty (LEC 3.0)
Optimization in the presence of model uncertainty or system stochasticity is discussed. The course covers fundamentals of stochastic programming, robust optimization, and dynamic programming. Prerequisite: Graduate standing. (Co-listed with ENG MGT 6415).

SYS ENG 6167 Software Intensive Systems Architecting (LEC 3.0)
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. 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.

SYS ENG 6213 Deep Learning and Advanced Neural Networks (LEC 3.0)
Use of deep learning and advance neural networks in the design of cyber physical complex adaptive systems. Machine learning basics, deep feed forward networks, regularization for deep learning, optimization for training deep models, convolutional networks, recurrent and recursive nets, practical , vision and natural language processing applications. Prerequisite: Graduate Standing.

SYS ENG 6214 Clustering Algorithms (LEC 3.0)
An introduction to 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. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Comp Sci 6405 and Stat 6239).

SYS ENG 6215 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), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Mech Eng 6458 and Aero Eng 6458).

SYS ENG 6216 Advanced Topics in Data Mining (LEC 3.0)
Advanced topics of current interest in the field of data mining. 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: A "C" or better grade in Comp Sci 5001 Introduction to Data Mining . (Co-listed with Comp Sci 6402 and Comp Eng 6302).

SYS ENG 6217 Markov Decision Processes (LEC 3.0)
Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisites: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Eng Mgt 6410, and Comp Sci 6202).

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. Prerequisites: Graduate Standing.

SYS ENG 6321 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. Prerequisites: Graduate Standing. (Co-listed with COMP ENG 6410).

SYS ENG 6322 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. Prerequisites: Sys Eng 6410, Comp Eng 6410, or Comp Eng 5420. (Co-listed with COMP ENG 6510).

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 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Elec Eng 6430).

SYS ENG 6412 Mathematical Programming (LEC 3.0)
Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Math 6665 and Eng Mgt 6412).

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 6612 Investment (LEC 3.0)
An introduction to the theory and practice of investment, including financial markets and instruments, security trading, mutual funds, investment banking, interest rates, risk premiums, the capital asset pricing model, arbitrage pricing theory, market efficiency, bonds and the fixed income market, equity valuation, fundamental and technical analysis. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6212).

SYS ENG 6613 Financial Engineering (LEC 3.0)
An introduction to financial engineering, with an emphasis on financial derivatives, including the future markets, the pricing of forwards and futures, forward rate agreements, interest and exchange rate futures, swaps, the options markets, option strategies, the binomial and Black-Scholes models for option valuation, the option Greeks, and volatility smiles. Prerequisites: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6213).

SYS ENG 6614 Financial Engineering II (LEC 3.0)
This course introduces advanced topics in financial engineering, which includes introduction to Wienver processes, martingales and Ito's lemma; basic numerical methods for options pricing, exotic options; interest rate models; stochastic volatility models and jump-diffusion models; and value-at-risk. Prerequisite: Eng Mgt 6213/Sys Eng 6613. (Co-listed with Eng Mgt 6214).

SYS ENG 6615 Financial Risk Management (LEC 3.0)
Techniques and methods for managing financial risk, including portfolio theory, Monte Carlo methods, ARIMA, time series forecasting, Value-at-Risk, stress testing, extreme value theory, GARCH and volatility estimation, random variables and probability distributions, real options, decision trees, utility theory, statistical decision techniques, and game theory. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6215).
