

Systems Science and Industrial Engineering

UNDERGRADUATE PROGRAMS

The bachelor of science program in industrial and systems engineering is a new program within the Watson School. The curriculum has been designed to seek engineering accreditation which can only be granted, as per the accreditation rules, after the first students have graduated. When obtained, the accreditation will be retroactive.

The curriculum provides a strong technical focus in industrial and systems engineering, combining a focus in engineering, manufacturing systems and business/information processing. Students at Binghamton enter the junior year from the Watson School Division of Engineering Design. The curriculum is also especially structured to enable transfer students to complete the program in accordance with the Two-Year Engineering Science Association (TYESA) agreement with community colleges in New York state.

The emphasis is on the application of engineering fundamentals with a balanced treatment of theory, design and experience or practice. Computer applications are integrated throughout the curriculum. During the senior year the student is allowed to select two electives. The senior year also has a primary focus on design; a two-course design sequence covers the concepts and terminates in a capstone design experience that is normally shared with industry.

The primary goal is to prepare the industrial and systems engineering bachelor of science graduate for a creative, lifelong engineering career based upon a thorough grounding in the fundamentals of engineering, a special focus on manufacturing systems and the integration of business/information processing.

Requirements for BS Degree in Industrial and Systems Engineering

To complete the BS degree in industrial and systems engineering, students must complete 63 credit hours in the upper division, as outlined below. The students must meet all of the University requirements for graduation, including

the General Education requirements. General Education requirements are waived for transfer students who have earned a minimum of 57 credits prior to entering the University. Any student with an associate degree in engineering science, or equivalent courses, will also have this waiver. For more information, students should contact the Watson School advising office.

<i>Junior Year/Semester I</i>	<i>credits</i>
ISE 311. Manufacturing Systems I	4
ISE 361. Analysis of Variability in Systems I .	4
Engineering elective	3
Humanities or social science elective*	4
TOTAL	15

<i>Junior Year/Semester II</i>	<i>credits</i>
ISE 312. Manufacturing Systems II	4
ISE 362. Analysis of Variability in Systems II .	4
ISE 370. Industrial Automation and Control .	4
Humanities or social science elective*	4
TOTAL	16

<i>Senior Year/Semester III</i>	<i>credits</i>
ISE 420. Optimization and Operations Research	4
ISE 463. Project Analysis and Control	4
ISE elective	4
ISE 491. Systems Design	4
TOTAL	16

<i>Senior Year/Semester IV</i>	<i>credits</i>
ISE 421. Modeling and Simulation	4
ISE 464. Elements of Fuzzy Logic and Fuzzy Set Theory	4
ISE elective	4
ISE 492. Systems Design Project	4
TOTAL	16

**from list provided by Watson advising*

MINOR IN COMPUTER SCIENCE

A minor in computer science is available for BSISE majors. Students may also apply for an extended program leading to dual degrees in industrial and systems engineering and computer science. For details, students should contact the Watson School advising office prior to registration.

GRADUATE PROGRAMS

The department offers multiple graduate-level degrees. The flexibility offered by the variety of programs helps students to follow their individual career paths. The two master of science programs available are the MS in systems science and the MS in industrial engineering. The department also offers a master of engineering degree in industrial engineering. Requirements for

admission are different for each degree program, as each serves students with different backgrounds.

The programs have the flexibility required by part-time students, EngiNet (distance) students and full-time students. The MEng degree program allows students the greatest flexibility within the systems science and industrial engineering areas and combines its offerings with several courses from other disciplines.

Master of Science in Systems Science

The graduate program in systems science provides the student with systems concepts, principles and methods for developing an ability to understand the nature of systems problems, as well as proficiency in actual systems problem solving. Involved are problem classes such as systems modeling and simulation, systems analysis and synthesis (systems design), as well as various problems associated with the simplification of overly complex systems to make them manageable.

The program emphasizes the complementary use of mathematical, computational and heuristic approaches to solving systems problems. Students learn to analyze assumptions under which various methods are applicable, with the aim of selecting methods that best fit the problem.

Requirements

Students with a baccalaureate degree (or its equivalent) in any field may apply for admission to this program. The student must maintain at least a B average in the following course of study:

- SSIE 500. Computational Tools
- SSIE 501. Introduction to Systems Science
- SSIE 505. Introduction to Applied Probability and Statistics
- SSIE 506. Systems Problem Solving
- SSIE 520. Modeling and Simulation
- SSIE 592. Professional Seminar (taken after 12 credit hours in the program)
- Four approved electives, including a 600-level course; and
- Termination requirement

NOTE: In special cases, a student may request an individualized program. If it deviates from the above requirements, it must be approved by the student's adviser and the department chair.

Students needing preparatory work may be advised to take appropriate undergraduate courses.

Some Sample Sequences

General Systems Sequence. The general systems sequence provides the student with firm conceptual foundations and tools for solving systems problems of universal nature through a well-organized general systems methodology. Emphasis is given to balanced use of mathematical and computational tools in the study of problems associated with complex systems.

In addition to the courses required of all students in the systems science specialization, the student takes the following courses:

- SSIE 606. Systems Problem Solving Workshop 2
- SSIE 617. Fuzzy Sets, Fuzzy Logic and Fuzzy Systems 3
- or alternatively*
- SSIE 518. Generalized Information Theory 2
- SSIE 650. Systems Optimization 3

This leaves six credits of graduate courses (500 or 600 level) to be chosen according to the interests of the student.

Systems Engineering Sequence. The systems engineering program is specifically designed for students with a BS in engineering, physics or math. The intent of the program is to focus on the systems engineer's concern with the integration of all aspects of systems, both technical and managerial. This may typically include design, production, deployment, operation, maintenance, modification and retirement, all within constraints of time, cost, personnel and other resources.

The course requirements for the systems engineering sequence vary slightly from those for the standard systems science specialization. The program must be approved by the MSSS adviser, and should be based on the following guidelines:

- SSIE 500. Computational Tools*
- SSIE 501. Introduction to Systems Science
- SSIE 505. Introduction to Applied Probability and Statistics*
- SSIE 525. Principles of Systems Engineering
- SSIE 526. Systems Engineering—Tools and Techniques*
- or*
- SSIE 520. Modeling and Simulation
- SSIE 527. Systems Design and Human Interactions*
- SSIE 528. Systems Engineering Project*
- Three approved electives, including a 600-level course
- Termination requirement

** For students with adequate backgrounds, electives may be substituted for one or both of these courses with permission from the adviser.*

**These courses subject to final approval.*

Doctoral Program in Systems Science

The PhD in systems science is described above under "Graduate Information."

Master of Science in Industrial Engineering

The master of science in industrial engineering provides a balance of theory and practical knowledge for the practice of the profession or for advancement to a doctoral program with an emphasis on manufacturing systems. In recognition of the high concentration of industry in the Binghamton area, this program has been structured to serve both the full- and part-time graduate student. Taking advantage of this industrial resource allows the program to develop a realistic approach to integrating manufacturing systems.

The academic environment of the department may be enriched by the appointment of adjunct faculty members employed in local industry. Under appropriate circumstances, thesis and/or project activity may be carried out in industrial laboratories.

REQUIREMENTS

Holders of the baccalaureate degree in industrial engineering or a related field are invited to apply for admission to this program. The GRE is required. A student whose undergraduate degree is not in industrial engineering may be required to complete some preparatory study in addition to the requirements listed below.

The student must maintain at least a B average in the following plan of study:

1. Four required courses:
 - SSIE 561. Quality Assurance
 - SSIE 520. Modeling and Simulation
 - SSIE 510. The Science of Manufacturing
 - SSIE 512. Integrated Manufacturing Systems
2. Four courses in an area of specialization or from a list of approved courses outside the department.
3. Complete either of the following independent study options:
 - a. Thesis: oral presentation and defense of the thesis are required.
 - b. Nonthesis: with departmental approval, the thesis requirement may be replaced by two approved elective courses and a project. Normally allowed only for part-time students.

Master of Engineering in Industrial Engineering

The master of engineering (MEng) in industrial engineering is a program that equips graduates with the skills needed to be effective in industry.

All MEng students must complete four approved courses in industrial engineering and four additional approved elective courses that may be chosen from other disciplines toward a particular academic goal. The specific courses in the program must be approved by the student's committee. In addition to these courses, the student must also complete the two-course sequence in Engineering Practice, which includes a practice-oriented project.

For more information on this degree, see also the School-Wide Graduate Program section of this *Bulletin*.

COURSE OFFERINGS/ UNDERGRADUATE

NOTE: Unless otherwise noted, undergraduate courses carry 4 credits.

ISE 311. MANUFACTURING SYSTEMS I

The major changes in the manufacturing process and the paradigm shifts in production are studied. Includes a focus on design, process improvement, inventory, teams, maintenance, planning and control systems, etc. Course is the first of two required for ISE majors. Prerequisites: EE 260 and ME 271 or equivalent.

ISE 312. MANUFACTURING SYSTEMS II

Second course in the manufacturing series. Covers the models, networking and systems needed to design and manage a manufacturing enterprise. Topics include MRP, Kanban, workstation design, facility design and other such manufacturing topics. Prerequisite: ISE 311 or consent of department chair.

ISE 361. ANALYSIS OF THE VARIABILITY IN SYSTEMS I

Discussion of practical aspects of data collection and descriptive statistics. Introduction to basic concepts of probability theory, Bayes theorem, probability distributions, point estimation and confidence interval inference from data, and test of hypothesis. Use of ANOVA. Discussion of regression and correlation. Use of control charts. Concepts of tolerance and methods for determining tolerances. Methods of off-line and on-line quality, determination of design parameters, and tolerance design. Prerequisite: Third year standing in ISE program or permission of the instructor.

ISE 362. ANALYSIS OF THE VARIABILITY IN SYSTEMS II

Review of ANOVA. Discussion of designing with experiments, including standard design of full factorial experiments, confounding and aliasing, Taguchi experiments, screening experiments and fractionalized factorial experiments. Concepts of non-parametric tests. Methods of fault isolation and failure mode analysis. Terms and concepts

relating to reliability and evaluation of reliability. Concepts of stochastic models, such as standby modeling and Markov models. Use of approximate methods and methods of testing and accelerated testing. Prerequisite: ISE 361 or permission of the instructor.

ISE 370. INDUSTRIAL AUTOMATION AND CONTROL

The different technologies employed to implement industrial automation are studied. Includes sensors, industrial robotics, numerical control, programmable logic controllers, machine vision and the implementation of on-line computer control. Laboratory work is required. Prerequisites: Third year standing in ISE or MATH 323, WTSN 212 and EE 260 or consent of department chair.

ISE 371. FUNDAMENTALS OF INTEGRATED MANUFACTURING

Concepts that help to integrate manufacturing systems are studied, including group technology, flexible manufacturing systems, computer-aided process planning, assembly line balancing, computer-aided design and manufacturing, concurrent engineering, supply chain management, etc. Necessary infrastructure and techniques critical to computer based integration addressed, including computer networking, databases and communication protocols within manufacturing. Prerequisite: Third-year standing in ISE or consent of department chair.

ISE 420. OPTIMIZATION AND OPERATIONS RESEARCH

Operations Research (OR) is devoted to the determination of the optimal course of action of a decision problem given resource restrictions. Following a review of linear algebra, the student learns the following: how to model an engineering problem mathematically, how to solve the problem to optimality and how to perform sensitivity analyses on the results. Students learn Linear Programming (LP), Integer Programming (IP), Dynamic Programming (DP) and Branch-and-Bound (B&B) techniques. Special emphasis placed on the solution of engineering decision making in the following areas: transportation models; project/production scheduling; inventory models; assignment problems. Prerequisite: ISE 362 or consent of department chair.

ISE 440. INTRODUCTION TO SYSTEMS SCIENCE

Includes the following: a general characterization of systems science as a field of study; intellectual roots, philosophical assumptions and historical development of the field; an overview of fundamental systems concepts, principles and laws; and a survey of application areas of systems science and its implications for other fields of study.

ISE 463. PROJECT ANALYSIS AND CONTROL

Covers the topics of project planning, economic decision making, costing and pricing. Topics include network planning, present worth, annual cost, rate of return, activity-based costing, inflation, price change, etc. Prerequisite: ISE 362 or consent of department chair.

ISE 464. ELEMENTS OF FUZZY LOGIC AND FUZZY SET THEORY 3 credits

A simple introduction to basic elements of fuzzy logic and fuzzy set theory, including an overview of classical logic and classical set theory. Included are basic concepts and properties of classical sets and fuzzy sets, classical relations and fuzzy relations, classical logic and fuzzy logic, and fuzzy arithmetic. The practical utility of fuzzy logic and fuzzy set theory is illustrated by describing selected applications in various areas of human affairs.

ISE 473. ELECTRONICS MANUFACTURING

The objective is to understand facets of electronics manufacturing, including the manufacture of printed circuit boards and the assembly of electronic devices using surface mount technology. Materials and processes related issues will be studied. Course includes a laboratory.

ISE 491. SYSTEMS DESIGN

Covers the design process from the definition of requirements through the final output. Focus is upon the design principles and design methodologies used to ensure a quality outcome. Prerequisites: ISE 311 and 362, or consent of department chair.

ISE 492. SYSTEMS DESIGN PROJECT

The termination design project for the undergraduate degree. Students are expected to work in teams to provide solutions through design. Prerequisite: ISE 491 or consent of the department chair.

ISE 497. INDEPENDENT STUDY

every semester, variable credit
Individual study under direct supervision of a faculty member. Prerequisites: approval of proposed subject by the faculty member and department chair.

COURSE OFFERINGS/ GRADUATE

NOTE: Unless otherwise noted, graduate courses carry 3 credits.

**Pending Graduate Council approval.*

SSIE 400. FUNDAMENTALS OF MATHEMATICS

Basic concepts of logic: truth tables, tautologies, valid arguments. Set theory: subsets, product sets, cardinality, functions and relations. Basic concepts of probability: real functions of real variable; derivative, integral, limit, continuity; interpolation, approximation: vectors and matrices.

SSIE 410. FUNDAMENTAL STRUCTURES

Covered concepts: sets, fuzzy sets, graph theory, trees, finite automata, Turing machines, formal languages, algebraic structures, semigroups, monoids, lattices, Boolean algebras, homomorphisms, isomorphisms, etc. Presented in terms applicable to modeling and simulation in systems and computer science. This class is available to undergraduate students as SSIE 310. Graduate students complete additional assignments. Prerequisite: SSIE 400 or equivalent.

SSIE 500. COMPUTATIONAL TOOLS

Prepares the student for the computer demands and opportunities involved in the design, analysis, modeling and simulation of complex systems. Each student develops a specific artificial life system demonstrating complex behavior. This system serves as the focal point for investigating modern tools associated with advanced research. Students develop proficiency in using object-oriented paradigms, contemporary programming languages (Java, C++, Smalltalk), symbolic computation (Mathematica, Maple, MathCad), spreadsheet analysis (Lotus, Excel, QuattroPro), discrete and continuous simulation languages (SIMAN, ARENA, Stella) and the Internet as research tools to enhance their computer modeling techniques and understanding. Emphasis is placed on integrating the results of these tool applications to produce a comprehensive, pro-

fessional report and presentation using word processing and presentation graphics packages. Prerequisite: graduate standing or consent of the department chair.

SSIE 501. INTRODUCTION TO SYSTEMS SCIENCE

Course includes: a general characterization of systems science as a field of study; intellectual roots, philosophical assumptions and historical development of the field; an overview of fundamental systems concepts, principles and laws; and a survey of application areas of systems science and its implications for other fields of study.

SSIE 505. APPLIED PROBABILITY AND STATISTICS

Basic concepts in probability and statistics required in the modeling of random processes and uncertainty. Bayes formula, Bayesian statistics, independence of events; random variables and their descriptive statistics; distribution and moment generating functions; Bernoulli trials, normal binomial hypergeometric, Poisson, exponential and multinomial distributions, Chebyshev's theorem; sampling, confidence intervals, estimation of parameters, Students-t, gamma X squared and F distributions; hypothesis testing, contingency tables, goodness of fit, nonparametric statistics, curve fitting, least squares, regression, correlation; maximum entropy principle. Prerequisites: SSIE 400 and one year of calculus.

SSIE 506. SYSTEMS PROBLEM SOLVING

A comprehensive conceptual framework for systems problem solving is introduced. Methods applicable to broad classes of problems discussed. Prerequisites: SSIE 410 and 505, and CS 340 or equivalent.

SSIE 510. THE SCIENCE OF MANUFACTURING

Manufacturing has become increasingly critical to our standard of living and to our competitive market position. Little has really been published and analyzed as to the underlying science of manufacturing. This course is designed to study the manufacturing literature and the manufacturing process and to investigate the underlying principles that govern manufacturing. Prerequisite: SSIE 505 or equivalent.

SSIE 511. ADVANCED PRODUCTION AND SCHEDULE CONTROL

Production scheduling and control. Design/production interface, bills of material, engineering revision control and general concepts of production planning and control for the engineer. Prerequisite: SSIE 510 or consent of department chair.

SSIE 512. INTEGRATED MANUFACTURING SYSTEMS

Integration of equipment, people and information required in total manufacturing systems. Product/process design, planning and support, procurement support, software/hardware. Prerequisite: graduate standing or consent of department chair.

SSIE 513. ADVANCED DESIGN FOR MATERIAL SYSTEMS

Material and material-related costs represent as much as one-half to two-thirds of today's manufacturing cost. The focus for a competitive manufacturing enterprise must be upon controlling and reducing these costs. This control and reduction will be brought about through an analysis of the total system, from purchase through the facility and out to the customer. Specific topics include: relationship buying, just-in-time, workstation design, handling systems design, facility design and distribution systems. Prerequisite: SSIE 510 or consent of department chair.

SSIE 516. FUZZY SET THEORY AND INFORMATION THEORY

2 credits

Overview of basic concepts of fuzzy set theory. Difference between probability theory and fuzzy set theory. Foundations of information theory. Uniqueness of information measures, maximum and minimum principles of information, fundamental properties of information. Prerequisites: SSIE 500 and 505, or equivalents.

SSIE 517. FUZZYSETS, UNCERTAINTY AND INFORMATION

Same subject areas as SSIE 516 (Fuzzy Set Theory and Information Theory), but some topics are covered at greater depth.

SSIE 518. GENERALIZED INFORMATION THEORY

Several new theories of uncertainty are introduced, including possibility theory, evidence theory and fuzzy set theory. Measures of information based on uncertainty reduction within these theories are examined in detail and compared with the classical measure of information formulated within the framework of probability theory (the Shannon entropy). Three important principles of uncertainty-based information are introduced, and their role in classical science, systems science, computer science, engineering and other areas of human affairs is discussed. Prerequisite: calculus and basic probability theory (e.g., SSIE 505).

SSIE 520. MODELING AND SIMULATION

4 credits

Approaches, methodologies and specific tools required in the modeling of complex systems. Stochastic systems, discrete event simulation, experimental statistics and elementary queueing theory. Dynamic behavior of continuous models. GPSS, Stella II, SAS, Minitab, SPSS or JMP. Decision, utility and game theory. Meta-modeling, adaptive linear machines. Sensitivity analysis, validity and precision of model. Prerequisites: SSIE 410 and 505 and CS 541, or equivalents.

SSIE 521. ANALYSIS OF SIMULATION RESULTS

Ability to analyze, understand and control complex manufacturing systems is enhanced through usage of simulation techniques. Topics include model development, theory, model validation, evaluation and analysis of the results, etc. Major emphasis on projects that are development models for actual manufacturing systems. Prerequisite: graduate standing or approval of department chair.

SSIE 525. PRINCIPLES OF SYSTEMS ENGINEERING

Provides the student with the basic principles of systems engineering applied in transforming client requirements into an operational system. Topics cover the full system lifecycle: planning, integrated product/process development, system architecture and design, modeling, requirements analysis, development, integration, test and evaluation. Specialized concepts involved in engineering complex systems are reinforced through case studies and student exercises. Prerequisite: graduate standing or permission of instructor.

SSIE 530. ANALYSIS OF PHYSICAL SYSTEMS I

Modeling and analysis of physical systems described by continuous functions of single independent variable. Mathematical models formulated; methods for solution presented. Emphasis on relationships among original system, mathematical model and mathematical solution. Prerequisites: one year of calculus and some ordinary differential equations.

SSIE 531 (also ME 530). MAN-MACHINE SYSTEMS

A systems engineering characterization of the human operator and the interaction with simple and complex machines, such as airplanes and ground vehicles. Topics include human perception, information measurement, manual control and mathematical modeling of the human operator. Modern control theory is employed to characterize the man-machine system. Prerequisite: BS in engineering or approval of department chair.

SSIE 535. ANALYTICAL METHODS

A survey and discussion of some of the more important and useful analytical methods for analyzing a wide variety of engineering and scientific problems. Topics include solution of differential equations, including methods for linear equations, power series, eigenfunction expansions and separation of variables; topics in multivariable calculus, including vector analysis; and selected topics in linear algebra, integral transforms and functions of a complex variable. Each of the methods is introduced in the context of real, applied problems and then illustrated with typical "real world" applications. Prerequisite: two semesters of calculus.

SSIE 536. NUMERICAL MODELING OF PHYSICAL PHENOMENA

Efficient and effective method for solving differential equations numerically. Single and multistep methods for initial value problems for ordinary differential equations; matrix and shooting methods for two-point boundary value problems; and shooting methods for eigenvalue-eigenfunction problems (for resonant frequency and mode shape calculations). Finite difference methods for partial differential equations, including the heat, wave and potential equations. Explicit and implicit methods, method of characteristics, Lax-Wendroff schemes and various methods to accelerate the convergence of the approximate solutions. Considerable emphasis is placed on the interpretation of the numerical solutions in terms of systems they model and the qualitative (as well as quantitative) insight they provide.

SSIE 541. JUSTIFYING NEW TECHNOLOGY

Traditional methods are reviewed against changes in manufacturing. Estimating, product cost vs. utilization, risk, sensitivity analysis and decision modeling. Prerequisite: basic course in engineering economics or its equivalent, or approval of department chair.

SSIE 545. HEURISTIC PROBLEM SOLVING

Concept of problem as cognitive dissonance. Methods of problem recognition, definition, solution, implementation, refinement. Intuitive approaches: analysis and syntheses; Meta-problem solving—development of strategies appropriate to problem type; inventive thinking: deferred judgment, metaphorical and visual thinking, finding order in chaos. Prerequisite: curiosity of creative process and genuine desire to innovate.

SSIE 546. THE PSYCHOLOGY OF PROBLEM SOLVING

Current topics in cognitive science, including perception, learning, pattern recognition, creativity, artificial intelligence, neural networks, brain theory, evolution of function.

SSIE 550. INTRODUCTION TO SYSTEMS OPTIMIZATION

Basic course in engineering optimization with emphasis on algorithms and applications. Topics: single variable optimization, multivariable optimization, Linear Programming (formulation, simplex method, interior point methods,

sensitivity analysis, applications), constrained optimization (Lagrange multipliers, Kuhn-Tucker conditions, direct search methods) and, time permitting, Quadratic Programming and linearization methods. Students gain enough proficiency to build optimization models of practical problems and solve them using tools learned in class. Use of available optimization computer codes.

SSIE 555. AUTOMATED SYSTEMS

Basic elements of automating a manufacturing process. Programmable logic controllers, data networks, parts orientation and feeding, robotics and systems integration. Prerequisite: SSIE 512 or approval of department chair.

SSIE 556. EXPERT SYSTEMS IN ELECTRONICS PACKAGING

Role of artificial intelligence-based expert systems in manufacturing as related to electronics packaging domain. Expert systems design and development as applied to electronics packaging. Knowledge acquisition and representation techniques solution spaces and search techniques, inference and deduction mechanism, and design and development of prototype systems. Prerequisite: graduate standing or approval of department chair.

SSIE 561. QUALITY ASSURANCE FOR ENGINEERS

Statistical quality control, designing for quality, process control, vendor and customer quality issues, quality costs and production. Prerequisites: BS in engineering (any field), and probability and statistics coursework, or consent of department chair.

SSIE 562. RELIABILITY

Reliability networks, failure mode and effect analysis, apportionment, fault trees and human reliability. Prerequisites: SSIE 561 and probability and statistics, or consent of department chair.

SSIE 566 (also ME 566). DESIGNING WITH EXPERIMENTS

Basics of applying statistical design, and the design function, statistical experimental design, control of experimental setting, Taguchi methods and analysis of results. Prerequisites: SSIE 561 and 505 or equivalents, or approval of department chair.

SSIE 570. BIOLOGICAL SYSTEMS THEORY

Models of biological organizations that complement structural, analytic concepts of molecular biology, and abstract, mathematical concepts of theories. Extension of these principles to ecological, social and cognitive levels of biological organizations.

SSIE 571. MODELING OF BIOLOGICAL SYSTEMS

Computer-based modeling of biological systems such as protein folding, protein biosynthesis, aggregation of cells into tissue, self-assembly of bacteriophages, origin of life and evolution, and neuron systems. Prerequisites: SSIE 400 or equivalent and equivalence of sophomore physics.

SSIE 575. SYSTEMS DESIGN

Systems approach to design process. Complex poorly defined, interdisciplinary problems. Design viewed as problem solving and opportunity development activity. User identification and satisfaction, adaptive design, design by attribute, design consciousness, models of design process. Prerequisite: open to students with advanced standing or professional experience.

SSIE 576 (also ME 571). MANUFACTURING PROCESSING I
Equilibrium and nonequilibrium microstructure arising from liquid-solid processing of materials. Casting of metal alloys, fusion welding of metals, injection molding of polymers, and brazing/soldering of metals. Prerequisite: BS in engineering or equivalent, or consent of department chair.

SSIE 577 (also ME 572). MANUFACTURING PROCESSING II
Role of mechanical and thermal forces on solid state fabrication of materials; extrusion, forging, particulate (powder) processing, rolling, sheet forming, wire drawing, heat treating and sintering. Prerequisites: strength of materials and heat transfer, or consent of department chair.

SSIE 578. PROCESSES FOR ELECTRONICS MANUFACTURING
The electrical content of manufactured products is increasing in all areas. To prepare the engineer for manufacturing these electrical assemblies, this course has been structured to cover topics in soldering, wire bonding, TAB, printed wiring board production, PCB assembly and population processes (through hole and SMT) and associated environmental issues. Prerequisite: undergraduate course in manufacturing processes, related experience or consent of department chair.

SSIE 580. SPECIAL TOPICS *1-4 credits*
Topics vary from semester to semester.

SSIE 590. SPECIAL TOPICS—INDUSTRIAL ENGINEERING SPECIAL PROBLEM
This course is based upon a basic understanding of industrial engineering. It varies and covers decision making in industrial or manufacturing engineering situations. Major emphasis is usually in manufacturing systems. Prerequisite: consent of department chair.

SSIE 592. PROFESSIONAL SEMINAR *2 credits*
Weekly seminar course conducted by faculty and outside speakers. Topics of current research. Each student goes into details of at least one of topics of seminar; through term paper, demonstrates in-depth understanding of topic to satisfaction of faculty. Prerequisite: student should be in last semester of master's program and have completed 12 credit hours.

SSIE 594. INDUSTRIAL INTERNSHIP
Industrial engineering, systems science and other professional experience. Daily log book, memo progress reports and a formal final report required. The internship may replace no more than one lecture course for the MSIE or MSSS degree. Prerequisite: permission of department chair.

SSIE 595. TERMINATION PROJECT: SYSTEMS SCIENCE *2 credits*
Project acceptable both to student and to a faculty committee. Inquire at Watson advising office to complete proper documentation. Prerequisite: consent of instructor and committee members.

SSIE 597. INDEPENDENT STUDY *1-4 credits*
Independent study supervised by department faculty member. Student must obtain consent of instructor, who then determines description of study program, number of credits, frequency of meetings, location.

SSIE 598. MSIE PROJECT
Literature review, manufacturing system development or other projects as defined by the project committee. Formal bound report for department library.

SSIE 599. THESIS RESEARCH *6 credits*
Training in the methods of research. Varied computer modeling, hardware development and experimentation as determined by the MSIE thesis committee. Oral examination required (eight credits total). Bound thesis goes in University library.

SSIE 606. SYSTEMS PROBLEM SOLVING WORKSHOP *2 credits*
Project-oriented course based on material covered in SSIE 506. Specific projects selected on basis both of interests of individual students and composition of group. Prerequisite: SSIE 506.

SSIE 612. ADVANCED TOPICS IN INTEGRATED MANUFACTURING
The continual need to improve quality and productivity and remain competitive in a global market requires the comprehensive integration of people, equipment, computers and information within a manufacturing systems engineering framework. This course is designed to study and analyze manufacturing integration issues with a special focus on integrating elements such as process planning, group technology, concurrent engineering, product quality, cost analysis, flexible manufacturing, inventory control, information flow and management, and global computer-integrated manufacturing (CIM) concept. Prerequisite: SSIE 512 or equivalent, or approval of department chair.

SSIE 617. FUZZY SETS, FUZZY LOGIC AND FUZZY SYSTEMS
Course consists of two parts. The first part covers fundamentals of fuzzy set theory and the associated fuzzy logic. The second part is devoted to applications of the theory. Topics of the theoretical part include: basic concepts of fuzzy set theory and fuzzy logic; representations of fuzzy sets; extension principle that facilitates fuzzifications of classical mathematical concepts; aggregation operations on fuzzy sets; the concept of a fuzzy number and arithmetic operations on fuzzy numbers; fuzzy relations; fuzzy relation equations; basic ideas of fuzzy logic; possibility theory based on fuzzy sets; and information aspects of fuzzy sets. In the application part, methods of constructing fuzzy sets in various application contexts are overviewed and representative applications of fuzzy sets and fuzzy logic are examined. The application areas covered include: systems science; approximate reasoning in expert systems; database and information retrieval systems; pattern recognition and image processing; decision making; medicine; economics; psychology; and various areas of engineering. Prerequisites: SSIE 505 or equivalent and calculus and discrete mathematics, or permission of instructor.

SSIE 618. FUZZY MEASURES: THEORY AND APPLICATIONS
Provides the student with a frame of the general theory of fuzzy measure. It includes some advanced knowledge on set theory (such as atom, s-compact, etc.), basic concepts of classical measure and fuzzy measure, structural characteristics of fuzzy measure, extension of fuzzy measure, concepts of "almost" and "pseudo-almost" on fuzzy measure space, measurable functions and convergence of their sequence on fuzzy measure space, concept and properties

of fuzzy integral, convergence theorems of sequence of fuzzy integrals, application of fuzzy integral in synthetical evaluation. Students will be asked to explore applications of these and related concepts in their areas of interest and write a term paper.

SSIE 620. ANALYSIS OF COMPLEX SYSTEMS

Techniques for and their applications to modeling and analyzing complex systems. Decision trees, graph theory, time series and forecasting, system identification, and nonlinear optimization, optimal allocation of resources, cluster analysis, queuing theory, analysis of specific complex systems. Prerequisites: SSIE 505, familiarity with simple differential equations.

SSIE 630. NEURAL NETWORK AND GENETIC MODELS

4 credits

The use of autonomous self-organizing models in deducing complex systems properties, behavior and relations; intelligence, learning, adaptation and emergence in artificial systems; perceptions and threshold logic units, discriminant functions, general nonparametric training; committee, piecewise linear, layered and parametric machines; evolutionary programming, genetic algorithms and satisficing vs. optimizing search strategies.

SSIE 632. PERTURBATION METHODS

Course focuses on application of perturbation methods to problems in engineering mechanics. Regular perturbation expansions, method of mathed (and composite) expansions, and method of multiple time scales are applied to problems drawn from such areas as vibrations, fluid mechanics, heat conduction, solid mechanics. Emphasis is on understanding the various methods discussed (e.g., what method applies to what kind of problem, what each method does and does not do, etc.) with applications used to illustrate the ideas. Prerequisites: two semesters of calculus and a course in ordinary differential equations.

SSIE 645. STATISTICAL MODELING WITH IMPRECISE PROBABILITIES

To deal with the uncertainty and the indeterminacy in systems, this course covers a new and increasingly important mathematical theory of imprecise probabilities, including upper probabilities and lower probabilities, based on three fundamental principles: avoiding sure loss, coherence and natural extension. Some useful models and strategies for assessing imprecise probability are introduced, and some applications to probabilistic reasoning, statistical inference and decision are discussed. Prerequisites: SSIE 505 and 516 or 517.

SSIE 650. SYSTEMS OPTIMIZATION

Broad spectrum of models and methods for systems optimization. Motivating examples; classical constrained and unconstrained methods; search techniques; linear programming; network and transportation systems, introduction to integer programming. Prerequisite: SSIE 520 or one year of calculus.

SSIE 656. ARTIFICIAL INTELLIGENCE IN MANUFACTURING

Artificial intelligence applied to scheduling, inventory control, process planning, maintenance; design and development of prototype systems; search techniques, knowledge representation. Prerequisite: SSIE 551 or equivalent, or consent of department chair.

SSIE 660. STOCHASTIC SYSTEMS

Discrete-state Markov chains; exponential and Poisson processes; reliability technology; birth and death proc-

esses; queuing models; renewal theory; continuous random variables; Kalman filters. Emphasis on applications. Prerequisite: SSIE 555 or equivalent.

SSIE 661. ADVANCED ISSUES IN QUALITY

The topic of quality has taken more and more of a critical nature for manufacturing systems. This course has two components. The first component is a practical application of the concepts of quality, including the design and execution of experiments in a real setting. The second component is the analysis and study of future issues in the field of quality, such as the development of loss equations, cost of high quality, and people and high quality. Prerequisite: SSIE 566 (Designing with Experiments) or a general design of experiments course.

SSIE 670. SELECTED TOPICS IN COGNITIVE SCIENCE

Topics will focus on current approaches to brain models and machine intelligence and on the different criteria that are used to evaluate such models. These approaches presently include programmable rule-based symbol systems (computationalism), coherent, distributed networks (connectionism) and models based on neurophysiology of simple and complex organisms. Special attention is given to the evolutionary and developmental constraints on the many functions of nervous systems and brains. Prerequisite: second-year graduate level course.

SSIE 680. ADVANCED SPECIAL TOPICS *1-4 credits*

Variable content, credit hours, prerequisites. When offered, covered topics, credit hours, prerequisites, text specified. NOTE: May be repeated for credit with consent of instructor. Prerequisite: to be announced.

SSIE 697. ADVANCED INDEPENDENT STUDY

Supervised by department faculty member. Student must obtain consent of instructor, who then determines description of program, number of credits, frequency of meeting and location. Appropriate paperwork must be submitted to complete registration.

SSIE 698. PREDISSENTATION *1-9 credits*

Research for and preparation of PhD dissertation.

SSIE 699. DISSERTATION *1-12 credits*

Research for and preparation of PhD dissertation.

SSIE 700. CONTINUOUS REGISTRATION

Required to maintain matriculation through any spring or fall semester when no other courses are taken. If minimal one-credit registration is not maintained, student must reapply for admission.

SSIE 701. PRACTICUM FOR RESEARCH AND TEACHING ASSISTANTS *every semester*

Required for all funded graduate assistants. Research or teaching supervised by faculty adviser.

SSIE 707. RESEARCH SKILLS *1 credit/semester*

Development of research skills required within graduate program. May not be applied toward course credits for any graduate degree.