Industrial and Systems Engineering

Interim Chair
• Geb W. Thomas

Undergraduate major: industrial engineering (B.S.E.)
Graduate degrees: M.S. in industrial engineering; Ph.D. in industrial engineering
Faculty: https://ise.engineering.uiowa.edu/people
Website: https://ise.engineering.uiowa.edu

The Department of Industrial and Systems Engineering offers distinct undergraduate and graduate degrees and research programs in industrial and systems engineering.

Industrial and systems engineering is concerned with analysis, design, and implementation of systems through optimal use of resources—human, material, energy, information, and financial. Systems may range from small units to extremely large operations. In order to accomplish these activities, the industrial engineer must be skilled in mathematics, physical sciences, management, and human relations as well as manufacturing, computer systems, economics, optimization, human behavior, and systems analysis and design.

Related Certificate

Transportation Studies
The Transportation Studies Program offers the Certificate in Transportation Studies. The program focuses on the varied and complex problems of transportation and on interdisciplinary approaches to addressing them. The Departments of Civil and Environmental Engineering, Industrial and Systems Engineering, Mechanical Engineering (College of Engineering), Economics (Tippie College of Business), Geographical and Sustainability Sciences (College of Liberal Arts and Sciences), and the School of Urban and Regional Planning (Graduate College) participate in the program.

The certificate is coordinated by the School of Urban and Regional Planning; see the Certificate in Transportation Studies in the Catalog.

Programs

Undergraduate Program of Study

Major
• Major in Industrial Engineering (Bachelor of Science in Engineering)

Graduate Programs of Study

Majors
• Master of Science in Industrial Engineering
• Doctor of Philosophy in Industrial Engineering

Facilities

The following facilities and laboratories are used by undergraduate and graduate students. For information about laboratories affiliated with core courses coordinated by other College of Engineering departments, see those departments' Catalog sections.

Additive Manufacturing-Integrated Product Realization Laboratory (AMPRL)

The research of AMPRL focuses on the study of how material forming processes existing in nature can be utilized to enable next-generation additive manufacturing (AM) technologies. Current research topics include:

• Next-generation AM technology development. The lab learns from nature how to develop next-generation AM technologies, which features multimaterial, multiscale, ultra-fast speed, energy-efficiency, among others.
• AM process modeling, quality control and optimization. The lab uses experimental and theoretical techniques to advance the understanding of fundamental physics behind nature-inspired AM processes and to achieve performance-driven process control.
• Novel applications of new AM technologies. The lab utilizes the unique capabilities of AM technologies to create devices for various applications, such as tissue engineering, sensing, energy harvest, robots, among others.

The lab has state-of-the-art material preparation, processing and characterization equipment, as well as several custom 3-D printers invented and developed by the group.

Graphical Representation of Knowledge Lab (GROK)

The GROK Lab develops technologies to help scientists and doctors improve their understanding and control of complex systems such as robots, distributed sensor networks, and augmented-reality systems. The lab designs and builds software, electronic circuits, and mechanical devices that create or modify complex systems that extend scientists’ understanding of how to make systems better perform intended tasks.

The lab has a variety of software development platforms and manufacturing tools, including computer numerical control (CNC) machines and supplies for casting and molding, as well as a suite of equipment for circuit design, testing, and assembly. The GROK lab has developed technologies used by NASA to control robots exploring South America and Mars. Its most recent projects have focused on using distributed sensor networks to track the activities of health care workers and on developing training simulators for orthopedic surgeons.

Information and Cognitive Systems Engineering Lab (ICSE)

Research in the ICSE lab focuses on design and analysis of cognitive work and information systems in real-world domains. Current emphasis is on cognitive work in health care systems.

Studies are conducted in usability testing, process mapping, cognitive walk throughs, discrete-event simulation, dynamic systems simulation, and interface design, prototyping, and evaluation. The research facility houses state-of-the-art qualitative field data collection equipment and data analysis tools, programming tools for discrete event and dynamic systems simulations, and design, prototyping, and usability-testing hardware and software tools for interface and display
design. The facility also employs data modeling, and mining and diagramming tools.

**Intelligent Systems Laboratory**

The Intelligent Systems Laboratory conducts research in data science and computational intelligence leading to applications in manufacturing, energy, service organizations, and health care. Research in the lab has been funded by government agencies and industrial corporations. Solutions to practical problems and enhancement of engineering education are emphasized. Most of the lab's recent projects concentrate on development of software tools for product development, manufacturing, and health care applications. Diverse software is available for modeling, design, and construction of intelligent systems.

**National Advanced Driving Simulator Laboratory (NADS)**

The NADS laboratory is home to the nation's largest and first public simulator of its kind in the world. For the last 25 years, the University of Iowa has conducted advanced research and development in support of saving lives, improving quality of life, advancing technology, and improving efficiency and productivity of the automotive and supporting industries. Most importantly, NADS serves as a place where students can learn firsthand about how innovation occurs in science and engineering.

From drug research to automated vehicles, NADS is dedicated to engaging in a broad, holistic approach. Faculty, staff, and students at NADS collaborate with nearly all University of Iowa colleges in their automotive safety research. Human factors research at NADS is funded by government agencies and industry leaders for public and private sectors. NADS supports undergraduate and graduate students in driving research studies. Many of these studies include the use of the NADS miniSimTM, a portable, high-performance driving simulator based on NADS' state-of-the-art driving simulation technology developed through decades of research. In-house workstations and computers equipped with software such as MATLAB, Visual Studio, R, and SAS are available to students with approved access to the facility.

**Operator Performance Laboratory (OPL)**

The Operator Performance Laboratory is a flight test organization. The OPL specializes in civilian and military flight testing and assessment of technologies in operational contexts such as flight in degraded visual environments (DVE) and GPS-denied environments. Quantification of data link and sensor performance for manned and unmanned aircraft in such operational context is an area of focus. OPL develops, tests, and evaluates helmet mounted displays (HMDs), synthetic vision systems (SVS), live virtual constructive (LVC) training systems, physiological-based workload measurement systems, pilot spatial orientation enhancement systems, and embedded flight simulation capabilities.

Unmanned aircraft operations include fifth- and sixth-generation manned-unmanned teaming (MUMT) concepts and the extension of LVC toward MUMT. The OPL team developed the cognitive assessment tool set (CATS), which is able to accurately quantify human cognitive workload using a flight-approved sensor package. CATS has been used in many flight tests as the data collection and analysis tool for pilot behavior in real-world flight environments. OPL pioneered the development and testing of LVC technology that blends ground-based battlespace simulations with airborne testbeds that have radar and weapons simulators that can employ simulated ordnance for effect in distributed simulation environments. The OPL team developed and tested a synthetic vision system that was commercialized by Dynon Avionics under the brand name Skyview.

OPL has performed many flight test projects on its fleet of aircraft, exceeding 2,200 flight hours of incident-free data collection. Eleven instrumented research aircraft comprise OPL's fleet.

**Visual Intelligence Laboratory**

The Visual Intelligence Laboratory conducts fundamental research to bridge state-of-the-art computational geometry, vision, and machine-learning technologies to real-world industrial applications such as computational human factor, autonomous driving, image-guided radiotherapy, medical image analysis, computational design and fabrication, among others. The lab strives to discover new mathematical theories and algorithms allowing the description, comparison, and algebraic (de)composition of shapes and visual features. Such mathematical understanding of shapes enables computers to see and understand the world and to become smarter assistants to humans.

The laboratory has a variety of imaging devices to obtain 2-D/3-D geometric information of various objects. The lab's imaging capacity includes the Studio360, a state-of-the-art imaging facility comprised of over 100 digital single-lens reflex (DSLR) cameras mounted on a 20-foot diameter geodesic dome. The Studio360 can capture time-synced photos/videos of dynamic objects (e.g., a person performing a motion) from multiple perspectives and reconstruct 3-D models of the objects. The lab also owns a high-performance computing server with 8x NVIDIA GeForce 1080Ti GPUs and 2x Intel Xeon E5 CPUs (total 48 threads) designated for massiv-scale image/geometry processing and deep learning.

The Visual Intelligence Laboratory has established broad academic research collaboration with a variety of entities across campus, including the Virtual Soldier Research (VSR) program, the National Advanced Driving Simulator (NADS), and University of Iowa Hospitals and Clinics (UIHC). In addition, the lab has been engaged in a number of research projects sponsored by government and industry partners, including the U.S. Department of Transportation, the U.S. Department of Defense, and a few international manufacturing companies.

**Shared Laboratory**

**Design for Manufacturing Laboratory**

The Design for Manufacturing Laboratory is used by students in industrial and systems engineering and in mechanical engineering. The laboratory provides students with experience in CAD/CAM systems. It is equipped with 4-axis CNC mills (Haas and Tormach), CNC router (Techno-CNC), CNC metal lathe (Haas and Techno-CNC), drill press, plastic injection molder, thermoforming machine, band saw, disc sander, bench grinder, polishing wheel, hand drill, sandblasting cabinet, press, foot shear, and welding station. The lab has the latest software technology, including Pro/ENGINEER and Rhinoceros.
Courses

Industrial and Systems Engineering Courses

IE:0000 Industrial Engineering Internship/Co-op  0 s.h.
Industrial engineering students participating in the Cooperative Education Program register in this course during work assignment periods; registration provides a record of participation in the program on the student's permanent record. Requirements: admission to Cooperative Education Program.

IE:1000 First-Year Seminar  0-1 s.h.
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

IE:2000 Industrial Engineering Sophomore Seminar  0 s.h.
Curriculum and profession; ethics and professionalism in classroom and workplace. Requirements: sophomore or transfer standing in engineering.

IE:2500 Engineering Economy  3 s.h.

IE:3000 Professional Seminar: Industrial Engineering  0 s.h.
Professional aspects of industrial engineering presented through lectures and discussions by guest speakers, field trips, films, panel discussions. Requirements: junior standing.

IE:3149 Information Visualization  3 s.h.
Instruments for reasoning about quantitative information; analyzing and communicating statistical information; main typologies of data graphics (data-maps, time-series, space-time narrative, relational diagrams, graphs and methods for dimensionality reduction); language for discussing data visualizations combined with knowledge of human perception of visual objects; how to visualize information effectively by using statistical methods, knowledge of human perception, and basics of data graphics. Prerequisites: STAT:2020.

IE:3300 Manufacturing Systems  3 s.h.
Manufacturing and logistics systems, supply chain management, MRP/ERP systems, lean manufacturing, concurrent engineering, value stream mapping and six sigma. Offered spring semesters. Prerequisites: IE:3700 and ENGR:2760. Same as ME:4131.

IE:3350 Process Engineering  4 s.h.
Methodologies, algorithms, and tools for processing modeling, analysis, and reengineering; modeling issues in product and component design, product and process modularity, quality, reliability, agility. Offered spring semesters. Prerequisites: IE:3700.

IE:3400 Human Factors  3 s.h.
Design of human-machine systems; development of optimum work environments by applying principles of behavioral science and basic knowledge of human capacities and limits. Offered fall semesters. Prerequisites: PSY:1001.

IE:3450 Ergonomics  3 s.h.
Ergonomic design of jobs and products in an industrial and consumer market setting; principles of good design, examples of poor design; consequences of poor job and product design; principles of work sampling, usability studies, performance rating, sizing and planning of workstations, hand tool design, ergonomic design in transportation; related group project.

IE:3500 Information Systems Design  3 s.h.
Structure and design of computer-based information systems; concepts of information systems, decision making; computer hardware, software, data structures; methods for determining system requirements; designing, implementing, evaluating, managing information systems; applied projects. Prerequisites: ENGR:1300.

IE:3600 Quality Control  3 s.h.
Basic techniques of statistical quality control; application of control charts for process control variables; design of inspection plans and industrial experimentation; modern management aspects of quality assurance systems. Offered fall semesters. Prerequisites: STAT:2020 or (STAT:3100 and STAT:3101 and STAT:3200). Same as CEE:3142, STAT:3620.

IE:3610 Stochastic Modeling  3 s.h.

IE:3660 Data Analytics with R  3 s.h.
Basics of data analytics and data mining; how to implement a variety of popular data mining methods in R to tackle business and engineering problems; focus on process of turning raw data into intelligent decisions and algorithms commonly used to build predictive models and find relevant patterns in data. Prerequisites: STAT:2020.

IE:3700 Operations Research  3 s.h.
Operations research models and applications; emphasis on deterministic model (linear programming, duality). Offered fall semesters. Prerequisites: MATH:2550. Corequisites: STAT:2020.

IE:3750 Digital Systems Simulation  3 s.h.
Simulation modeling and analysis; emphasis on construction of models, interpretation of modeling results; input and output analysis; hands-on usage of ARENA simulation software, manufacturing, health care, and service. Offered spring semesters. Prerequisites: IE:3610 and IE:3700.

IE:3760 Applied Linear Regression  3 s.h.
Regression analysis with focus on applications; model formulation, checking, selection; interpretation and presentation of analysis results; simple and multiple linear regression; logistic regression; ANOVA; hands-on data analysis with computer software. Prerequisites: STAT:2020 or STAT:2100. Same as IGPI:3200, STAT:3200.

Independent projects in industrial engineering for undergraduate students, including laboratory study, an engineering design project, analysis and simulation of an engineering system, computer software development, CAD/CAM applications, or research.
IE:4113 Control of Mechanical Engineering Systems 3 s.h.
How to model simple engineering systems, apply time and frequency domain analysis techniques, and design control systems; application of these techniques using MATLAB; writing differential equations describing engineering systems and determine time domain response to a wide range of inputs; use of state-variable equations to model engineering systems and determine their time response to a wide range of inputs; describe advantages of feedback control; analyze performance of control systems; determine stability of control systems using Root-Locus, Bode, and Nyquist methods; design feedback control systems using frequency domain and state-variable methods. Prerequisites: MATH:2550 and MATH:2560 and ENGR:2710. Same as ME:4113.

IE:4116 Manufacturing Processes Simulations and Automation 3 s.h.
Material processing, metal cutting theories, forming, micro/nano fabrication, programmable logic controller, computer numerical controllers, discrete control system, DC and AC servo motors, Command generation. Prerequisites: ENGR:2760. Same as ME:4116.

IE:4172 Big Data Analytics 3 s.h.
Principles of data mining and machine learning in context of big data; basic data mining principles and methods—pattern discovery, clustering, ordering, analysis of different types of data (sets and sequences); machine learning topics including supervised and unsupervised learning, tuning model complexity, dimensionality reduction, nonparametric methods, comparing and combining algorithms; applications of these methods; development of analytical techniques to cope with challenging and real "big data" problems; introduction to MapReduce, Hadoop, and GPU computing tools (Cuda and OpenCL). Prerequisites: STAT:2020. Requirements: basic programming skills in C, C++, Java, or Python; knowledge of Matlab, Octave, or R; and knowledge of a word processor. Recommendations: IE:3760 and CS:4400 and CS:3330 and MATH:2550.

IE:4175 Safety Engineering 3 s.h.
Systems safety principles and methods, occupational safety, product safety and liability, accident investigation and prevention methods and analysis, hazard analysis, and standards and regulations.

IE:4550 Wind Power Management 3 s.h.
Principles of wind power production, wind turbine design, wind park location and design, turbine and wind park control, predictive modeling, integration of wind power with a grid.

IE:4600 Industrial Engineering Design Project 1-4 s.h.
Projects involving product and related operational system design in an industrial or service organization; associated entrepreneurial or intrapreneurial planning. Corequisites: IE:3300 and IE:3350 and IE:3400 and IE:3450 and IE:3500 and IE:3600 and IE:3750, if not taken as prerequisites.

IE:4620 Design of Experiments for Quality Improvement 3 s.h.
Development of skills necessary to efficiently and effectively design and analyze experiments for quality improvement; topics include experiment planning, design, and statistical analysis of the results; experimentation is beneficial in all phases of industrial processes including new product design, process development, and manufacturing process improvement; students develop successful experiments that can lead to reduced development lead time, enhanced process performance, and improved product quality. Prerequisites: STAT:2020. Requirements: junior (third year) standing.

IE:4650 Mechatronics Engineering for Smart Device Design 3 s.h.
Introduction to basic mechatronics system components and design principles using mechatronics to meet functionality requirements of products, processes, and systems; lab-oriented assignments and team-based projects presented with innovative case studies in diverse application domains; labs require students to use a micro-controller kit to finish hardware development assignments; for students who plan to have a career in areas such as product development, robotics, design and manufacturing automation, technology management and innovations. Prerequisites: ENGR:2120 and ENGR:2760. Same as ME:4650.

IE:4900 Introduction to Six Sigma 3 s.h.
Six Sigma techniques for the DMAIC cycle (Define, Measure, Analyze, Improve, Control); what is needed for data collection (process inputs and outputs, measurement tools), conduct analysis (hypothesis testing, process capability studies), and conduct process improvement studies (design of experiments, response surface methodology); overview of Six Sigma, process and project management skills; application of the DMAIC model to a real-life improvement projection (a "learn-by-doing" approach). Prerequisites: IE:3600.

IE:5000 Graduate Seminar: Industrial Engineering 1 s.h.
Recent advances and research in industrial engineering presented by guest lecturers, faculty, students. Requirements: graduate standing.

IE:5420 Automated Vehicle Systems 3 s.h.
Overview of vehicle technologies (HAV) and advanced driver assistance systems (ADAS) including a historical perspective, testing, policy and regulation, algorithm design, and human factors. Recommendations: IE:3400.

IE:5860 Health Informatics I 3 s.h.
Technological tools that support health care administration, management, and decision making. Same as HMP:5370, IGPI:5200, MED:5300, SLIS:5900.

IE:5995 Contemporary Topics in Industrial Engineering arr.
New topics or areas of study not offered in other industrial engineering courses; topics based on faculty/student interest.

Individual projects for industrial engineering graduate students; laboratory study, engineering design, analysis and simulation of an engineering system, computer software development, research. Requirements: graduate standing.

Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for M.S. with thesis in industrial engineering. Requirements: graduate standing.
IE:6211 Human Factors in Healthcare Systems 3 s.h. Solving human factors problems in health care work systems; cognitive systems engineering, interface design, health care productivity, patient safety; specific research including decision making, information transfer, and communication; discrete event and dynamic systems simulation modeling; human computer interaction; health information technology/ systems; usability; business models of organizational, technical, and social elements of health care systems.

IE:6220 Cognitive Engineering 3 s.h. Cognitive engineering principles; decision making and judgment; distributed cognition; cognitive work; human system interaction; cognitive work analysis; situated action and ecological models; mental models and representation; cognitive engineering methods and applications.

IE:6232 Advanced Computer-Aided Design and Manufacturing 3 s.h. In-depth study of CAD and manufacturing (CAD/CAM); review of CAD/CAM, computer graphics, NURBS modeling (curves/surfaces, solid modeling, design data exchange); computational geometry for product development, heterogeneous object modeling, rapid prototyping (RP) and layered manufacturing, computer-aided path planning, CAD applications (computer-aided tissue engineering, biomedical imaging and processing, biomanufacturing); related lab projects and assignments. Requirements: knowledge of one programming language (C, C++, C#, VB, or Java).

IE:6300 Innovation Science and Studies 3 s.h. Innovative typology and sources, classical innovation models, measuring innovation, innovation discovery from data, evolutionary computation in innovation, innovation life cycle.

IE:6350 Computational Intelligence 3 s.h. Concepts, models, algorithms, and tools for development of intelligent systems; data mining, expert systems, neural networks for engineering, medical and systems applications. Prerequisites: IE:3700. Same as NURS:6900.

IE:6410 Research Methods in Human Factors Engineering 3 s.h. Logic and methods for research and for analysis and evaluation of complex human-machine systems; advanced techniques for enhancement of human interaction with advanced information technology; emphasis on cognitive task analysis techniques for innovative design, understanding of how technology affects safety, performance, user acceptance.

IE:6420 Human/Computer Interaction 3 s.h. Development of projects using human factors principles in the design of computer interfaces.

IE:6440 Airborne Design of Experiments 3 s.h. Issues in design of airborne human factors research, and techniques applicable to ground transportation research; statistical, human factors, flight mechanics, and organizational principles in flight test engineering; basic understanding of systematic approach to human factors flight testing, development of test points and test apparatus, flight envelope, proper briefing techniques, mission execution, and after-action review; securing, synchronizing, and analyzing data.

IE:6450 Human Factors in Aviation 3 s.h. Measuring, modeling, and optimizing human visual performance; display design for optimal legibility, research in visibility, legibility, conspicuity, and camouflage; visibility model development.

IE:6460 The Design of Virtual Environments 3 s.h. Development of techniques for designing and creating three-dimensional representations of information for simulation, scientific visualization, and engineering; emphasis on human factors issues, software.

IE:6480 Unmanned Aircraft Systems 3 s.h. Applications and research in unmanned aircraft systems (UAS) with focus on engineering aspects; new era of aviation and how UAS are fast emerging as a disruptive technology in aviation; applications ranging from film production, photography, precision agriculture, remote sensing, and infrastructure inspections to military applications; problem space of UAS from a variety of angles including engineering controls design, data links, UAS types, human factors, regulatory aspects.

IE:6600 Linear Programming 3 s.h. Mathematical programming models; linear and integer programming, transportation models, large-scale linear programming, network flow models, convex separable programming. Requirements: calculus and linear algebra. Same as IGPI:6600, MSCI:6600.

IE:6720 Nonlinear Optimization 3 s.h. Mathematical models, theory, algorithms for constrained and unconstrained nonlinear optimization; optimality conditions and aspects of duality theory; applications of nonlinear optimization in data analytics and machine learning.

IE:6750 Stochastic Optimization 3 s.h. General tools and approaches used in decision making under uncertainties; modeling of uncertainties and risk, changes that uncertainties bring to the decision process, difficulties of incorporating uncertainties into optimization models, common techniques for solving stochastic problems.

IE:6760 Pattern Recognition for Financial Data 3 s.h. Modeling and harvesting useful information and patterns for financial data; topics include basic concepts of financial data, financial data visualization, modeling and forecasting of financial time series, seasonal models, volatility models, value at risk, principal component analysis, and factor models.

IE:6780 Financial Engineering and Optimization 3 s.h. Quantitative methods of modeling various financial instruments (i.e., stocks, options, futures) and tools for measurement and control of risks inherent to financial markets; fundamentals of interest rates; options and futures contract valuation, including weather and energy derivatives; risk management and portfolio optimization; emphasis on modeling and solution techniques based on optimization and simulation approaches traditional to industrial engineering and operations research. Recommendations: basic knowledge of probability and statistics, numerical methods, and optimization.

IE:6790 Reliability Theory and Applications 3 s.h. Fundamental topics in reliability engineering, including system reliability modeling, statistical inference of lifetime data, basic preventive maintenance models; statistics and random process models, and online monitoring and change detection techniques. Prerequisites: MATH:2550 and STAT:2020.
IE:6810 Advanced Topics on Additive Manufacturing 3 s.h.
Review of critical challenges facing 3-D printing; emphasis on techniques and practical experience in developing novel additive manufacturing processes and applications; topics include 3-D content creation and preparation, CAD systems for additive manufacturing, additive manufacturing processes, fabrication speed and improvements, rapid tooling and indirective processes. Same as ME:6810.

IE:7995 Advanced Topics: Industrial Engineering arr.
Discussion of current literature in industrial engineering.

IE:7998 Special Topics in Industrial Engineering arr.

Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for Ph.D. in industrial engineering.