MANAGEMENT SCIENCE AND ENGINEERING

Courses offered by the Department of Management Science and Engineering are listed under the subject code MS&E on the [ExploreCourses web site](https://explorecourses.stanford.edu/search?view=catalog&AcademicYear=2018-19&filter-departmentcode-MS%26E=on&filter-coursestatus-Active=on&filter-term-Autumn=on)Stanford Bulletin’s ExploreCourses web site.

The Department of Management Science and Engineering leads at the interface of engineering, business, and public policy. The department's mission is, through education and research, to advance the design, management, operation, and interaction of technological, economic, and social systems. The department’s engineering research strength is integrated with its educational program at the undergraduate, master's, and doctoral levels: graduates of the program are trained as engineers and future leaders in technology, policy, and industry. Research and teaching activities are complemented by an outreach program that encourages the transfer of ideas to the environment of Silicon Valley and beyond.

Management Science and Engineering (MS&E) provides programs of education and research by integrating three basic strengths:

1. depth in conceptual and analytical foundations
2. comprehensive coverage of functional areas of application
3. interaction with other Stanford departments, Silicon Valley industry, and organizations throughout the world.

The analytical and conceptual foundations include decision and risk analysis, dynamic systems, economics, optimization, organizational science, and stochastic systems. The functional areas of application include entrepreneurship, finance, information, marketing, organizational behavior, policy, production, and strategy. Close associations with other engineering departments and with industry enrich the programs by providing opportunities to apply MS&E methods to important problems and by motivating new theoretical developments from practical experience. MS&E’s programs also provide a basis for contributing to other areas such as biotechnology, defense policy, environmental policy, information systems, and telecommunications.

Mission of the Undergraduate Program in Management Science and Engineering

The mission of the undergraduate program in Management Science and Engineering is to provide students with the fundamentals of engineering systems analysis so that they are able to plan, design, and implement complex economic and technical management systems. The program builds on the foundational courses for engineering including calculus, engineering fundamentals, and physics or chemistry as well as management science. Students complete core courses in accounting, computer science, economics, ethics, organizational theory, mathematical modeling, optimization, probability, and statistics. To personalize their exploration, students select additional courses from different areas of the department, with greater emphasis in one of them. The major prepares students for a variety of career paths, including investment banking, management consulting, facilities and process management, or for graduate school in industrial engineering, operations research, business, economics, law, medicine, or public policy.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to be able:

1. to apply the knowledge of mathematics, science, and engineering;
2. to design and conduct experiments;
3. to design a system or components to meet desired needs;
4. to identify, formulate, and solve engineering problems;
5. to use techniques, skills, and modern engineering tools necessary for engineering practice;
6. to function on multidisciplinary teams;
7. to communicate effectively;
8. to recognize the need for and demonstrate an ability to engage in lifelong learning;
9. to obtain the background necessary for admission to top professional graduate engineering or business programs;
10. to understand professional and ethical responsibility;
11. to obtain the broad education necessary to understand the impact of engineering solutions in a global and societal context; and
12. to obtain a knowledge of contemporary issues pertinent to the field of management science and engineering.

Graduate Programs in Management Science and Engineering

MS&E offers programs leading to the degrees of Master of Science and Doctor of Philosophy. The department also offers a coterminal B.S./M.S. degree, a dual master’s degree in cooperation with each of the other departments in the School of Engineering, and joint master's degrees with the School of Law and the Public Policy Program.

For University coterminal degree program rules and University application forms, see the Registrar's coterminal degrees web site [http://studentaffairs.stanford.edu/registrar/publications/#Coterm](http://studentaffairs.stanford.edu/registrar/publications/#Coterm).

Applicants for admission as graduate students in MS&E are required to submit the results of the verbal reasoning, quantitative reasoning, and analytical writing sections of the Graduate Record Examination General Test (GRE). The deadline for application to the doctoral program is December 3, 2019, and the deadline for application to the master's program is January 14, 2020.

Except in unusual circumstances, admission is limited to the Autumn Quarter because courses are arranged sequentially with basic courses and prerequisites offered early in the academic year.

Assistantships and Fellowships

A limited number of fellowships and assistantships are awarded each year. Applicants admitted to the doctoral program, who have indicated on their application that they would like to be considered for financial aid, are automatically considered for these assistantships and fellowships. New and returning master’s students may apply for course assistantships each quarter, but priority is given to MS&E doctoral students.

Information about loan programs and need-based aid for U.S. citizens and permanent residents can be obtained from the Financial Aid Office.

Learning Outcomes (Graduate)

The M.S. prepares engineers for a lifelong career addressing the technical and managerial needs of private and public organizations. The program emphasizes developing analytic abilities, making better decisions, developing and executing strategies while also leading people who innovate. Unlike an M.B.A., our master's program addresses the technical as well as the behavioral challenges of running organizations
and complex systems. We emphasize quantitative analytic skills and an entrepreneurial spirit.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Management Science and Engineering and related fields.

Careers in MS&E
MS&E students are candidates for careers in consulting, product and project management, financial analysis, and work in policy arenas. A significant number join or found start-ups. Many have become leaders in technology-based businesses which have an increasing need for analytically oriented people who understand both business and technology. Other graduates make careers tackling the problems faced by local, national, and international governments by developing new healthcare systems, new energy systems and a more sustainable environment. The major problems of the day demand an ability to integrate the technical, social and economic ways of thinking. This is precisely what the department educates its students to do.

Bachelor of Science in Management Science and Engineering
The program leading to the B.S. degree in Management Science and Engineering (MS&E) is outlined in the School of Engineering section of this bulletin, more information is contained in the School of Engineering's Handbook for Undergraduate Engineering Programs. Students are encouraged to plan their academic programs as early as possible, ideally in the freshman or sophomore year. Students should not wait until they are declaring a major to consult with the department's student services staff. This is particularly important for students who would like to study overseas or pursue another major or minor.

Completion of the undergraduate program in Management Science and Engineering provides students training in the fundamentals of engineering systems analysis to prepare them to plan, design, and implement complex economic and technological management systems where a scientific or engineering background is necessary or desirable. The major prepares students for a variety of career paths, including investment banking, management consulting, facilities and process management, or for graduate school in industrial engineering, operations research, business, economics, law, medicine, or public policy.

The educational objectives of the undergraduate degree program are:

- **Principles and Skills**—provide students with a basic understanding of management science and engineering principles, including analytical problem solving and communications skills.
- **Preparation for Practice**—prepare students for practice in a field that sees rapid changes in tools, problems, and opportunities.
- **Preparation for Continued Growth**—prepare students for graduate study and self-development over an entire career.
- **Preparation for Service**—develop in students the awareness, background, and skills necessary to become responsible citizens, employees, and leaders.

See also the department’s undergraduate Learning Outcomes (p.) for additional learning objectives.

The program builds on the foundational courses for engineering, including calculus, mathematical modeling, probability, statistics, engineering fundamentals, and physics or chemistry.

Students interested in a minor should see the Minor tab in this section.

MS&E also participates with the departments of Computer Science, Mathematics, and Statistics in a program leading to a B.S. in Mathematical and Computational Science. See the "Mathematical and Computational Science (http://explorerdegrees.stanford.edu/schoolofhumanitiesandsciences/mathematicalandcomputationalscience/#bachelorstext)" section of this bulletin.

Core
The department core, taken for all areas, includes courses in accounting, computer science, deterministic optimization, economics, organization theory, and a capstone senior project. Through the core, students in the program are exposed to the breadth of faculty interests, and are in a good position to choose an area during the junior year.

Areas
The major is designed to allow a student to explore all three areas of the department in greater depth.

1. **Finance and Decision** focuses on the design and analysis of financial and strategic plans.
2. **Operations and Analytics** focuses on algorithms, theory, and the design and analysis of manufacturing, production, and service systems.
3. **Organizations, Technology, and Policy** focuses on understanding, design, and analysis of organizations and public policy, particularly technology-based issues.

Management Science and Engineering (MS&E)
Completion of the undergraduate program in Management Science and Engineering leads to the conferral of the Bachelor of Science in Management Science and Engineering.

Requirements

<table>
<thead>
<tr>
<th>Mathematics and Science</th>
<th>Units</th>
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<tbody>
<tr>
<td>Up to ten units of AP/IB Calculus, MATH 19, 20, 21, 41, or 42.</td>
<td>10</td>
</tr>
<tr>
<td>All required; see SoE Basic Requirements 1 and 2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>CME 100 or MATH 51</td>
<td>Vector Calculus for Engineers</td>
<td>23</td>
</tr>
<tr>
<td>CME 103</td>
<td>Introduction to Matrix Methods</td>
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</tr>
<tr>
<td>MS&amp;E 120</td>
<td>Probabilistic Analysis</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 121</td>
<td>Introduction to Stochastic Modeling</td>
<td></td>
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<tr>
<td>MS&amp;E 125</td>
<td>Introduction to Applied Statistics</td>
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<tr>
<td>Select two of the following:</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>CHEM 31B</td>
<td>Chemical Principles II</td>
<td></td>
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<tr>
<td>CHEM 33</td>
<td>Structure and Reactivity of Organic Molecules</td>
<td></td>
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<tr>
<td>PHYSICS 41 or PHYSICS 21</td>
<td>Mechanics</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 43 or PHYSICS 23</td>
<td>Electricity and Magnetism</td>
<td></td>
</tr>
<tr>
<td>BIO 81</td>
<td>Introduction to Ecology</td>
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<tr>
<td>BIO 82</td>
<td>Genetics</td>
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<tr>
<td>BIO 83</td>
<td>Biochemistry &amp; Molecular Biology</td>
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<tr>
<td>BIO 84</td>
<td>Physiology</td>
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<tr>
<td>BIO 85</td>
<td>Evolution</td>
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</tr>
<tr>
<td>BIO 86</td>
<td>Cell Biology</td>
<td></td>
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</tbody>
</table>

Math, Science, or Statistics Elective from SoE approved lists. | 3 |
Technology in Society
Select one of the following; see SoE Basic Requirement 4
AA 252 Techniques of Failure Analysis
COMM 120W The Rise of Digital Culture
BIOE 131 Ethics in Bioengineering
CS 181 Computers, Ethics, and Public Policy
ENGR 117 Expanding Engineering Limits: Culture, Diversity, and Equity
ENGR 148 Principled Entrepreneurial Decisions
ME 267 Ethics and Equity in Transportation Systems
MS&E 193 Technology and National Security: Past, Present, and Future
POLISCI 114S International Security in a Changing World
STS 1 The Public Life of Science and Technology

Engineering Fundamentals
Two courses; see SoE Basic Requirement 3
CS 106A Programming Methodology

Select one of the following:
ENGR 10 Introduction to Engineering Analysis
ENGR 14 Intro to Solid Mechanics
ENGR 15 Dynamics
ENGR 20 Introduction to Chemical Engineering
ENGR 21 Engineering of Systems
ENGR 25B Biotechnology
ENGR 25E Energy: Chemical Transformations for Production, Storage, and Use
ENGR 40A Introductory Electronics
ENGR 40M An Intro to Making: What is EE
ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis
ENGR 50E Introduction to Materials Science, Energy Emphasis
ENGR 50M Introduction to Materials Science, Biomaterials Emphasis
ENGR 80 Introduction to Bioengineering (Engineering Living Matter)
ENGR 90 Environmental Science and Technology

Engineering Depth
Core Courses (all six required)
CS 106B Programming Abstractions
or CS 106X Programming Abstractions
ECON 50 Economic Analysis I
MS&E 108 Senior Project (WIM)
MS&E 111 Introduction to Optimization
or MS&E 111X Introduction to Optimization (Accelerated)
MS&E 140 Accounting for Managers and Entrepreneurs
MS&E 180 Organizations: Theory and Management

Area Courses (see below)
Choose four courses from a primary area and two courses from each of the other two areas.

Depth Areas

Finance and Decision Area
Students choosing F&D as their primary area must take at least two of ECON 51, MS&E 145 (or 245A), and MS&E 152 (or 252).

Intermediate (has prerequisites and/or appropriate for juniors and seniors)
MS&E 145 Introduction to Finance and Investment
MS&E 146 Corporate Financial Management
MS&E 252 Decision Analysis I: Foundations of Decision Analysis

Advanced (intended primarily for graduate students, but may be taken by advanced undergraduates)
MS&E 245A Investment Science
MS&E 245B Advanced Investment Science
MS&E 246 Financial Risk Analytics
MS&E 250A Engineering Risk Analysis
MS&E 250B Project Course in Engineering Risk Analysis

Operations and Analytics Area
Students choosing O&A as their primary area may also include CS 161, CS 229, and STATS 202 in their selections

Methods
MS&E 112 Mathematical Programming and Combinatorial Optimization
MS&E 135 Networks
MS&E 213 Introduction to Optimization Theory
MS&E 223 Simulation
MS&E 226 Fundamentals of Data Science: Prediction, Inference, Causality
MS&E 231 Introduction to Computational Social Science
MS&E 251 Introduction to Stochastic Control with Applications

Applications
MS&E 130 Information Networks and Services
MS&E 232 Introduction to Game Theory
MS&E 234 Data Privacy and Ethics
MS&E 260 Introduction to Operations Management
MS&E 263 Healthcare Operations Management
MS&E 267 Service Operations and the Design of Marketplaces
MS&E 330 Law, Bias, & Algorithms
MS&E 463 Healthcare Systems Design

Organizations, Technology, and Policy Area
Students choosing OT&P as their primary area must take at least two of ENGR 145, MS&E 175, MS&E 182A, MS&E 182B, MS&E 184, and MS&E 185.

Introductory (no prerequisites)
ENGR 148 Principled Entrepreneurial Decisions
MS&E 190 Methods and Models for Policy and Strategy Analysis
MS&E 193 Technology and National Security: Past, Present, and Future

Advanced (has prerequisites and/or appropriate for juniors and seniors)
BIOE 177 Inventing the Future
or MS&E 177
ENGR 145 Technology Entrepreneurship
MS&E 175 Innovation, Creativity, and Change
MS&E 182A Leading Organizational Change
MS&E 182B Leading Organizational Change II
Management Science and Engineering (MS&E) Minor

The following courses are required to fulfill the minor requirements:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
</tr>
<tr>
<td>or MATH 51</td>
<td>Linear Algebra, Multivariable Calculus, and Modern Applications</td>
</tr>
<tr>
<td>CS 106A</td>
<td>Programming Methodology</td>
</tr>
<tr>
<td>MS&amp;E 111</td>
<td>Introduction to Optimization</td>
</tr>
<tr>
<td>or MS&amp;E 111X</td>
<td>Introduction to Optimization (Accelerated)</td>
</tr>
<tr>
<td>MS&amp;E 120</td>
<td>Probabilistic Analysis ¹</td>
</tr>
<tr>
<td>MS&amp;E 121</td>
<td>Introduction to Stochastic Modeling</td>
</tr>
<tr>
<td>MS&amp;E 125</td>
<td>Introduction to Applied Statistics</td>
</tr>
<tr>
<td>MS&amp;E 180</td>
<td>Organizations: Theory and Management</td>
</tr>
<tr>
<td>Electives</td>
<td>(select any two 100- or 200-level MS&amp;E courses)</td>
</tr>
</tbody>
</table>

Recommended courses

In addition to the required background and minor courses, it is recommended that students also take the following courses.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 50</td>
<td>Economic Analysis I</td>
</tr>
<tr>
<td>MS&amp;E 140</td>
<td>Accounting for Managers and Entrepreneurs (may be used as one of the required electives above)</td>
</tr>
</tbody>
</table>

¹ Students completing a calculus-based probability course such as CS 109 or STAT 116 for their major, may substitute another MS&E course for MS&E 120.

Coterminal Program in Management Science and Engineering

This program allows Stanford undergraduates an opportunity to work simultaneously toward a B.S. in Management Science and Engineering or another quantitative major, and an M.S. in Management Science and Engineering.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science in Management Science and Engineering

The M.S. degree programs require a minimum of 45 units beyond the equivalent of a B.S. degree at Stanford. All programs represent substantial progress in the major field beyond the bachelor's degree.

University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

The master's in Management Science and Engineering prepares engineers for a lifelong career addressing the technical and managerial needs of private and public organizations. The program emphasizes developing analytic abilities, making better decisions, and developing and executing strategies while also leading people who innovate. Unlike an M.B.A., the department's master's program addresses the technical as well as the behavioral challenges of running organizations and complex systems, emphasizing quantitative analytic skills and an entrepreneurial spirit.

MS&E students know math, engineering, as well as behavioral science. They can conduct experiments to design better systems, organizations and work processes. They understand how to analyze data to solve real world problems. They can develop mathematical and computational models to inform action. They know how to surface and examine unarticulated assumptions and root causes. These students can communicate effectively in the team environments found in so many contemporary organizations.
MS&E master's students have breadth as well as depth. All are required to develop competence in optimization and analytics, organizations and decisions, and probability. In addition every student pursues a specialty in one of seven areas:

1. **Financial Analytics**: Students who concentrate in Financial Analytics are prepared for careers requiring analytical rigor and the ability to innovate around market challenges. Example career paths include financial services, risk management, investment management, financial technology and data processing, financial regulation and policy, exchanges and clearing houses, and auditing and compliance. The concentration combines the in-depth study of quantitative techniques with practical, hands-on business problem solving. Students learn to use mathematical models and quantitative tools to solve complex problems in finance practice. The concentration exploits the intellectual ties between finance, operations research, computer science, and engineering. It offers a high level of flexibility and a range of elective courses that allow students to tailor the program to their specific career goals. Required courses immerse students in quantitative methods and deepen their understanding of finance fundamentals. Projects courses feature practical, data-driven team projects and case studies, fostering group learning and interaction with peers.

2. **Operations and Analytics**: The Operations and Analytics track prepares students in the fundamentals and applications that are critical to careers in fields ranging from operations management in the service, healthcare, production, manufacturing, computer, telecommunications, and banking industries, to modern Silicon Valley information technology and data analytics. The program emphasizes a balance between the technical rigor of methodologies with lasting value and insightful modern applications and design challenges in a variety of established and emerging industries and operations environments. It offers a portfolio of courses in probabilistic modeling, optimization, simulation, algorithms, data science, networks, markets, and corresponding applications.

3. **Technology and Engineering Management**: Students who concentrate in Technology and Engineering Management are prepared for careers including product and project management, management consulting, and entrepreneurship. They acquire skills to manage technical organizations, foster innovation, and deal with rapidly evolving technologies and dynamic markets. Specialized coursework is flexible, allowing students to explore and gain depth and understanding of technical organizations to develop a culture of successful innovation and entrepreneurship, along with methods for decision making under uncertainty, financial analysis, and strategic planning.

4. **Computational Social Science**: The Computational Social Science track teaches students how to apply rigorous statistical and computational methods to address problems in economics, sociology, political science, and beyond. The program prepares students for a diverse set of career paths in data science, information technology, and policy analysis. The core coursework covers fundamental statistical concepts, large-scale computation, and network analysis. Through electives, students can explore topics such as experimental design, algorithmic economics, and machine learning.

5. **Decision and Risk Analysis**: Students who specialize in Decision and Risk Analysis are prepared for careers including management consulting, policy analysis, and risk management, applying engineering systems analysis to tackle complex economic and technical management problems in the private and public sectors. They acquire the skills to identify and develop opportunities in uncertain situations while recognizing and hedging the downside risks. Specialized course work includes the mathematical foundations for modeling in dynamic uncertain environments to value and manage uncertain opportunities and risks, applications to public policy, and an opportunity to work on a client project under faculty guidance.

6. **Energy and Environment**: The Energy and Environment track is designed for students interested in energy and environmental issues from the perspectives of public policy, non-governmental organizations, or corporations. This track includes core courses in economic analysis, energy resources, and energy/environmental policy analysis; and an individually designed concentration, typically emphasizing policy, strategy, or technology. Seminars provide insights into current corporate strategy, public policy, and research community developments. Energy/environmental project courses give practice in applying methodologies and concepts.

7. **Health Systems Modeling**: The Health Systems Modeling track is designed for students interested in healthcare operations and policy. The courses in this track emphasize the application of mathematical and economic analysis to problems in public health policy and the design and operation of healthcare services.

The master's degree is designed to be a terminal degree program with a professional focus. The M.S. degree can be earned in one academic year (three academic quarters) of full-time work, although most students choose to complete the program in five academic quarters, or eighteen months, and work as an intern in the Summer Quarter.

**Background Requirements**
Students are expected to have completed both MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications, or an equivalent multivariable differential calculus course, and CS 106A Programming Methodology, or an equivalent general programming course, before beginning graduate study. These courses do not count toward degree requirements.

**Degree Requirements**
Students must take a minimum of 45 course units as follows:

- Three core courses (9-12 units)
- Four to six courses in a primary or specialized concentration (12-24 units)
- One project course or two integrated project courses (0-8 units)
- Elective courses (1-24 units; see restrictions below)

**Core Courses (three courses required)**

**Optimization and Analytics (select one)**

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>MS&amp;E 211</td>
<td>Introduction to Optimization</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 211X</td>
<td>Introduction to Optimization (Accelerated)</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 213</td>
<td>Introduction to Optimization Theory</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 226</td>
<td>Fundamentals of Data Science: Prediction, Inference, Causality</td>
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</tbody>
</table>

Relevant 200 or 300 level MS&E course in optimization or analytics if a comparable introductory course in optimization or analytics has already been completed.

**Organizations and Decisions (select one)**

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>MS&amp;E 252</td>
<td>Decision Analysis I: Foundations of Decision Analysis</td>
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</tr>
<tr>
<td>MS&amp;E 270</td>
<td>Strategy in Technology-Based Companies</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 280</td>
<td>Organizational Behavior: Evidence in Action</td>
<td></td>
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</tbody>
</table>

Relevant 200 or 300 level MS&E course in organizations or decisions if a comparable introductory course in organizations or decisions has already been completed.

**Probability (select one)**

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 220</td>
<td>Probabilistic Analysis</td>
<td></td>
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<tr>
<td>MS&amp;E 221</td>
<td>Stochastic Modeling</td>
<td></td>
</tr>
</tbody>
</table>
Relevant 200 or 300 level MS&E course in probability or stochastics if a comparable introductory course in probability or stochastics has already been completed.

Primary Concentrations (may not duplicate Core courses)

Financial Analytics Concentration (five courses required)

Financial Theory and Modeling (select one):
- MS&E 245A Investment Science
- MS&E 245B Advanced Investment Science
- MS&E 246 Financial Risk Analytics

Quantitative Methods (two required):
Select one (whichever of optimization or analytics wasn't taken for core):
- MS&E 211 Introduction to Optimization
- MS&E 211X Introduction to Optimization (Accelerated)
- MS&E 213 Introduction to Optimization Theory
- MS&E 226 Fundamentals of Data Science: Prediction, Inference, Causality

Select one:
- MS&E 223 Simulation
- MS&E 245B Advanced Investment Science (if not used above)
- MS&E 246 Financial Risk Analytics (if not used above)
- MS&E 322 Stochastic Calculus and Control
- MS&E 349 Financial Statistics
- STATS 207 Introduction to Time Series Analysis
- STATS 240 Statistical Methods in Finance

Operations and Analytics Concentration (four courses required)

Required Courses
- MS&E 211X Introduction to Optimization (Accelerated) (whichever of optimization or analytics wasn’t taken for core)
- MS&E 213 Introduction to Optimization Theory
- MS&E 226 Fundamentals of Data Science: Prediction, Inference, Causality
- MS&E 221 Stochastic Modeling (a more advanced course in probability or stochastics (i.e. MS&E 223 Simulation) if a student has taken an equivalent class in stochastic modeling)
- MS&E 212 Mathematical Programming and Combinatorial Optimization
- MS&E 232 Introduction to Game Theory
- MS&E 251 Introduction to Stochastic Control with Applications
- CS 229 Machine Learning

Units

Technology and Engineering Management Concentration (four courses required)

Courses for Core and Concentration must cover each of the three sub-areas below.

Organizations and Strategy (select one):
- MS&E 265 Introduction to Product Management
- MS&E 270 Strategy in Technology-Based Companies
- MS&E 274 Dynamic Entrepreneurial Strategy
- MS&E 278 Patent Law and Strategy for Innovators and Entrepreneurs
- MS&E 280 Organizational Behavior: Evidence in Action
- MS&E 284 Designing Modern Work Organizations

Entrepreneurship and Innovation (select one):
- MS&E 270 Strategy in Technology-Based Companies
- MS&E 271 Global Entrepreneurial Marketing
- MS&E 272 Entrepreneurship without Borders
- MS&E 273 Technology Venture Formation
- CEE 246 Venture Creation for the Real Economy
- MS&E 275 Intelligent Growth in Startups
- MS&E 276 Entrepreneurial Management and Finance
- MS&E 277 Creativity and Innovation
- ENGR 245 The Lean LaunchPad: Getting Your Lean Startup Off the Ground
- ENGR 248 Principled Entrepreneurial Decisions

Finance and Decisions (select one):
- MS&E 240 Accounting for Managers and Entrepreneurs
- MS&E 245A Investment Science
- MS&E 245B Advanced Investment Science
- MS&E 246 Financial Risk Analytics
- MS&E 249 Corporate Financial Management
- MS&E 250A Engineering Risk Analysis
- MS&E 250B Project Course in Engineering Risk Analysis
- MS&E 252 Decision Analysis I: Foundations of Decision Analysis

Units

Note: CS 229 and CS 246 may be taken to satisfy this requirement in 2019-2020 only, since neither 212 nor 251 will be offered in 2019-2020.
Management Science and Engineering

MS&E 355 Influence Diagrams and Probabilistics Networks

Select one additional course from any sub-area above

Specialized Concentrations (must have approval of the academic adviser)
Computational Social Science (four courses required)

Statistics (select at least one)
- MS&E 226 Fundamentals of Data Science: Prediction, Inference, Causality
- STATS 203 Introduction to Regression Models and Analysis of Variance
- STATS 305A Applied Statistics I
- STATS 315A Modern Applied Statistics: Learning
- STATS 315B Modern Applied Statistics: Data Mining

Computation (select at least one)
- MS&E 231 Introduction to Computational Social Science
- CS 224N Natural Language Processing with Deep Learning
- CS 229 Machine Learning
- CS 246 Mining Massive Data Sets

Networks (select at least one)
- MS&E 233 Topics in Social Data
- CS 224W Machine Learning with Graphs
- ECON 291 Social and Economic Networks

Social Science (select at least one)
- MS&E 232 Introduction to Game Theory
- MS&E 241 Economic Analysis
- MS&E 270 Strategy in Technology-Based Companies
- MS&E 280 Organizational Behavior: Evidence in Action
- MS&E 284 Designing Modern Work Organizations
- ECON 202N Microeconomics I For Non-Economics PhDs
- PSYCH 212 Classic and contemporary social psychology research
- PSYCH 265 Social Psychology and Social Change
- SOC 220 Interpersonal Relations
- SOC 224B Relational Sociology

Recommended Elective Courses
Causal Inference
- COMM 382 Big Data and Causal Inference
- POLISCI 355C Causal Inference for Social Science

Computation
- MS&E 234 Data Privacy and Ethics
- CS 147 Introduction to Human-Computer Interaction Design
- CS 229 Machine Learning
- CS 448B Data Visualization

Economics
- MS&E 241 Economic Analysis

Natural Language Processing
- CS 124 From Languages to Information
- CS 224N Natural Language Processing with Deep Learning
- CS 224S Spoken Language Processing
- POLISCI 452 Machine Learning with Application to Text as Data

LINGUIST 278 Programming for Linguists

Networks
- SOC 369 Social Network Methods

Psychology
- PSYCH 216 Public Policy and Social Psychology: Implications and Applications
- PSYCH 238 Wise Interventions

Sociology
- SOC 214 Economic Sociology
- SOC 218 Social Movements and Collective Action
- SOC 262 The Social Regulation of Markets
- SOC 270 Classics of Modern Social Theory
- SOC 271

Statistics
- STATS 209 Statistical Methods for Group Comparisons and Causal Inference
- STATS 263 Design of Experiments
- STATS 315A Modern Applied Statistics: Learning
- STATS 315B Modern Applied Statistics: Data Mining

Decision and Risk Analysis Concentration (four courses required)

Core Courses are restricted as follows:
- MS&E 211 Introduction to Optimization
  or MS&E 211X Introduction to Optimization (Accelerated)
- MS&E 221 Stochastic Modeling
- MS&E 252 Decision Analysis I: Foundations of Decision Analysis

Required Courses (select two):
- MS&E 241 Economic Analysis
- MS&E 250A Engineering Risk Analysis
- MS&E 251 Introduction to Stochastic Control with Applications
  or EE 263 Introduction to Linear Dynamical Systems
- MS&E 355 Influence Diagrams and Probabilistics Networks

Policy Course (select one):
- MS&E 243 Energy and Environmental Policy Analysis
- MS&E 292 Health Policy Modeling
- MS&E 293 Technology and National Security: Past, Present, and Future

Project Course:
- MS&E 250B Project Course in Engineering Risk Analysis
- MS&E 297 "Hacking for Defense": Solving National Security issues with the Lean Launchpad

Energy and Environment Concentration (six courses required)

Required Courses:
- MS&E 241 Economic Analysis
- MS&E 243 Energy and Environmental Policy Analysis
- CEE 207A Understanding Energy
  or CEE 273S Electricity Economics
- ENERGY 291 Optimization of Energy Systems

Three additional courses from energy, policy, or strategy areas below.
Policy:
- MS&E 292 Health Policy Modeling
Health Systems Modeling and Policy Concentration (four courses required)

<table>
<thead>
<tr>
<th>Required Courses (select four)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 293 Technology and National Security: Past, Present, and Future</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 394 Advanced Methods in Modeling for Climate and Energy Policy</td>
<td></td>
</tr>
<tr>
<td>ECON 251 Natural Resource and Energy Economics</td>
<td></td>
</tr>
</tbody>
</table>

Strategy:

| MS&E 270 Strategy in Technology-Based Companies |       |
| MS&E 271 Global Entrepreneurial Marketing |       |
| MS&E 272 Entrepreneurship without Borders |       |
| MS&E 273 Technology Venture Formation |       |
| MS&E 274 Dynamic Entrepreneurial Strategy |       |
| MS&E 275 Intelligent Growth in Startups |       |
| MS&E 276 Entrepreneurial Management and Finance |       |
| MS&E 277 Creativity and Innovation |       |
| MS&E 278 Patent Law and Strategy for Innovators and Entrepreneurs |       |

Energy:

| ENERGY 102 Fundamentals of Renewable Power |       |
| ENERGY 104 Sustainable Energy for 9 Billion |       |
| ME 370A Energy Systems I: Thermodynamics |       |
| ME 370B Energy Systems II: Modeling and Advanced Concepts |       |
| PHYSICS 240 Introduction to the Physics of Energy |       |
| PHYSICS 241 Introduction to Nuclear Energy |       |

Recommended Seminars:

| MS&E 441 Policy and Economics Research Roundtable |       |
| MS&E 472 Entrepreneurial Thought Leaders’ Seminar |       |
| ECON 341 Public Economics and Environmental Economics Seminar |       |
| ENERGY 301 The Energy Seminar |       |

Recommended Elective Courses:

| MS&E 256 Technology Assessment and Regulation of Medical Devices |       |
| HRP 256 Economics of Health and Medical Care |       |
| HRP 391 Health Law: Finance and Insurance |       |

Projects (may duplicate Core and/or Concentration courses)
Select one project course or two integrated project courses.

<table>
<thead>
<tr>
<th>Project Courses</th>
<th>Units</th>
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<tbody>
<tr>
<td>MS&amp;E 250B Project Course in Engineering Risk Analysis</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 348 Optimization of Uncertainty and Applications in Finance</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 448 Big Financial Data and Algorithmic Trading</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 463 Healthcare Systems Design</td>
<td>3-4</td>
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</tbody>
</table>

Integrated Project Courses

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 248 Principled Entrepreneurial Decisions</td>
</tr>
<tr>
<td>MS&amp;E 201 Dynamic Systems</td>
</tr>
<tr>
<td>MS&amp;E 226 Fundamentals of Data Science: Prediction, Inference, Causality</td>
</tr>
<tr>
<td>MS&amp;E 243 Energy and Environmental Policy Analysis</td>
</tr>
<tr>
<td>MS&amp;E 245A Investment Science</td>
</tr>
<tr>
<td>MS&amp;E 245B Advanced Investment Science</td>
</tr>
<tr>
<td>MS&amp;E 246 Financial Risk Analytics</td>
</tr>
<tr>
<td>MS&amp;E 252 Decision Analysis I: Foundations of Decision Analysis</td>
</tr>
<tr>
<td>MS&amp;E 256 Technology Assessment and Regulation of Medical Devices</td>
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<tr>
<td>MS&amp;E 260 Introduction to Operations Management</td>
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<tr>
<td>MS&amp;E 265 Introduction to Product Management</td>
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<tr>
<td>MS&amp;E 270 Strategy in Technology-Based Companies</td>
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<tr>
<td>MS&amp;E 271 Global Entrepreneurial Marketing</td>
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<tr>
<td>MS&amp;E 272 Entrepreneurship without Borders</td>
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<td>MS&amp;E 273 Technology Venture Formation</td>
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<td>MS&amp;E 274 Dynamic Entrepreneurial Strategy</td>
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<td>MS&amp;E 275 Intelligent Growth in Startups</td>
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<td>MS&amp;E 277 Creativity and Innovation</td>
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<td>MS&amp;E 280 Organizational Behavior: Evidence in Action</td>
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<td>MS&amp;E 284 Designing Modern Work Organizations</td>
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<td>MS&amp;E 311 Optimization</td>
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<td>MS&amp;E 338 Reinforcement Learning</td>
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<td>MS&amp;E 347 Credit Risk: Modeling and Management</td>
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<tr>
<td>MS&amp;E 349 Financial Statistics</td>
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<tr>
<td>MS&amp;E 355 Influence Diagrams and Probabilistics Networks</td>
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</tbody>
</table>

Additional Requirements

1. At least 45 units must be in courses numbered 100 and above.
2. The degree program must be completed with a grade point average (GPA) of 3.0 or higher.
3. At least 27 units must be in courses numbered 200 and above in MS&E, taken for a letter grade and a minimum of two units each.
4. At least 36 letter-graded units must be in MS&E or closely related fields. Closely related fields include any department in the School of Engineering, mathematics, statistics, economics, sociology, or business.
5. A maximum of 4 units of directed or individual study units may count toward the letter-grade requirement.
6. All courses used to satisfy core, concentration, or project requirements must be taken for a letter grade.
7. A maximum of three units of 1-unit courses such as seminars, colloquia, workshops, in any department, including MS&E 208A, B, C, and D Practical Training, and MS&E 208E Part-Time Practical Training.
8. A maximum of 18 non-degree option (NDO) units through the Stanford Center for Professional Development (SCPD).
9. Courses taken in Health and Human Performance (e.g. Athletics, Club Sports, Kinesiology, Leadership Innovations, Lifeworks, Outdoor Education, Physical Education, and Wellness Education) may not be applied toward the degree.

Professional Education
The Stanford Center for Professional Development (SCPD) provides opportunities for employees of some local and remote companies to take courses at Stanford.

The Honors Cooperative Program (HCP) provides opportunities for fully employed working professionals to earn an M.S. degree, over a longer period, by taking one or two courses per academic quarter. Some courses are only offered on campus; HCP students may attend those courses at Stanford to meet the degree requirements. It is possible to complete this program as a remote HCP student although the remote offerings are limited. Students must apply for a degree program through the standard application process, and must meet the standard application deadlines.

The non-degree option (NDO) program allows industry students with the opportunity to take Stanford graduate courses on a part-time basis without having to be formally admitted to a degree program. NDO students enroll as distance learners where up to 18 units of graduate credit earned may later be applied toward a degree program (if admitted). Students who have completed an undergraduate degree with a minimum of a 3.0 grade point average, may apply to take MS&E courses online each quarter through the Stanford Center for Professional Development. Completion of multivariable calculus and linear algebra is required for most MS&E courses and graduate certificates. For additional information about the NDO application process and deadlines, see the SCPD web site (http://scpd.stanford.edu/non-degree-option-program), or contact SCPD at (650) 725-3000.

Certificate
The department offers a certificate program within the framework of the NDO program. A certificate can be obtained by completing three MS&E core courses, plus one MS&E elective course for a total of four courses. For further information, see http://scpd.stanford.edu/programs/graduate-certificates.

Dual Master's Degree Program
The dual degree program enables a small group of graduate students to obtain two master's degrees simultaneously. Students complete the course requirements for each department. A total of 90 units is required to complete the dual master's degree.

Admission
For the dual degree, admission to two departments is required, but is coordinated by designated members of both admissions committees who make recommendations to the committees of their respective departments. Students may apply to only one department initially. After the first quarter at Stanford, students may apply to be admitted to the second department.

Advising
Every student in the dual degree program has one adviser in each department.

Joint MS&E and Law Degrees
The School of Law and the Department of Management Science and Engineering offer joint degree programs leading to a J.D. degree and an M.S. degree in MS&E, or to a J.D. and Ph.D. in MS&E. These programs are designed for students who wish to prepare themselves for careers in areas relating to both law and to the decision making, policy making, and problem solving knowledge and skills developed in the MS&E program. Students interested in either joint degree program must apply and gain admission separately to the School of Law and the Department of Management Science and Engineering and, as an additional step, must secure consent from both academic units to pursue degrees in those units as part of a joint degree program. Interest in either joint degree program should be noted on the student's admission applications and may be considered by the admission committee of each program. Alternatively, an enrolled student in either the Law School or MS&E may apply for admission to the other program and for joint degree status in both academic units after commencing study in either program.

Joint degree students may elect to begin their course of study in either the School of Law or MS&E. Students are assigned to a joint program committee composed of at least one faculty member from Law and one from MS&E. This committee plans the student's program jointly with the student. Students must be enrolled full time in the Law School for the first year of law studies, and it is recommended that students devote exclusively one Autumn Quarter to the MS&E M.S. program to initiate their MS&E work. After that time, enrollment may be in MS&E or Law, and students may choose courses from either program regardless of where enrolled. A candidate in the joint J.D./Ph.D. program should spend a substantial amount of full time residency in MS&E. Students must satisfy the requirements for both the J.D. and the M.S. or Ph.D. degrees as specified in this bulletin or by the School of Law. The Law School may approve courses from MS&E or courses in the student's MS&E program from outside of the Department of Management Science and Engineering that may count toward the J.D. degree, and MS&E may approve courses from the Law School that may count toward the M.S. or Ph.D. degree in MS&E. In either case, approval may consist of a list applicable to all joint degree students or may be tailored to each individual student's program. The lists may differ depending on whether the student is pursuing an M.S. or a Ph.D. in MS&E.

In the case of a J.D./M.S. program, no more than 45 units of approved courses may be counted toward both degrees. In the case of a J.D./Ph.D. program, no more than 54 units of approved courses may be counted toward both degrees. In either case, no more than 36 units of courses that originate outside the Law School may count toward the J.D. degree, and MS&E may approve courses from the Law School that may count toward the M.S. or Ph.D. degree in MS&E. In either case, approval may consist of a list applicable to all joint degree students or may be tailored to each individual student's program. The lists may differ depending on whether the student is pursuing an M.S. or a Ph.D. in MS&E.

Joint MS&E and Master of Public Policy Degree
M.S. MS&E students who wish to apply their analytical and management skills to the field of public policy can simultaneously pursue a master degree in MS&E and a master degree in Public Policy. The MPP is a two-year degree program, but M.S. MS&E students who pursue the joint program can earn both degrees in a minimum of two years, depending on...
prior preparation and elective choices, by counting up to 45 quarter units of course work toward both degrees. After admission to the Department of Management Science and Engineering, incoming or current M.S. students request that their application file be forwarded to the MPP program director for review.

Students in the joint program normally will spend most of their first year taking MS&E core courses. The second year is typically devoted to the MPP core, concentration, and practicum. The joint degree requires 90 quarter units. Tuition for the first year of study is paid at the Graduate Engineering rate, the remaining time at the graduate rate.

Doctor of Philosophy in Management Science and Engineering

University requirements for the Ph.D. degree are described in the “Graduate Degrees” section of this bulletin.

The Ph.D. degree in MS&E is intended for students primarily interested in a career of research and teaching, or high-level technical work in universities, industry, or government. The program requires three years of full-time graduate study, at least two years of which must be at Stanford. Typically, however, students take four to five years after entering the program to complete all Ph.D. requirements. The Ph.D. is organized around the expectation that the students acquire a certain breadth across all areas of the department, and depth in one of them. The current areas are:

- Computational Social Science
- Decision Analysis and Risk Analysis
- Energy and Environment
- Quantitative Finance
- Health Systems Modeling and Policy
- National Security Policy
- Operations Management
- Optimization and Stochastics
- Organizations
- Strategy, Innovation, and Entrepreneurship

Doctoral students are required to take a number of courses, both to pass a qualifying exam in one of these areas, and to complete a dissertation based on research which must make an original contribution to knowledge.

Each student admitted to the Ph.D. program must satisfy a breadth requirement and pass a qualification procedure. The purpose of the qualification procedure is to assess the student’s command of the field and to evaluate his or her potential to complete a high-quality dissertation in a timely manner. The student must complete specified course work in one of the areas of the department.

The qualification decision is based on the student’s course work and grade point average (GPA), on the one or two preliminary papers prepared by the student with close guidance from two faculty members, at least one of whom must be an MS&E faculty member, the student’s performance in an area examination or defense of the written paper(s), and an overall assessment by the faculty of the student’s ability to conduct high-quality Ph.D. research. Considering this evidence, the department faculty vote on advancing the student to candidacy in the department at large. The Ph.D. requires a minimum of 135 units, up to 45 units of which may be transferred from another graduate program.

In addition, during the second year, a student must pass an examination in one of the areas of the MS&E department, or defense of the written paper(s). The student chooses the area/
program in which to take the examination. This area examination is written, oral, or both, at the discretion of the area faculty administering the exam. Most areas offer the qualifying exam only once per year, which may be early in the second year.

Degree Progress and Student Responsibility
Each doctoral student’s progress is reviewed annually by the MS&E faculty. Typically, this occurs at a faculty meeting at the end of Spring Quarter, and an appropriate email notification is sent over the summer to the student and their adviser. It shall be the responsibility of the student to initiate each required step in completing the Ph.D. program.

1. To maintain good standing in the degree program, first-year students must:
   a. complete 30 units, including MS&E 302 and doctoral courses taught by faculty in their research area;
   b. develop relationships with faculty members who can potentially serve as dissertation adviser or reading committee member. A faculty member is more likely to accept the responsibility of supervising the research of a student whom he or she knows fairly well than a student whose abilities, initiative, and originality the faculty member knows less well. It is recommended that students participate in research rotations with MS&E and related faculty to facilitate the development of these relationships.

2. To maintain good standing in the degree program second-year students must:
   a. submit a candidacy form signed by at least one MS&E faculty member with whom they have or will complete research rotations, tutorials, or papers, and listing the course requirements agreed upon by both the student and the program adviser;
   b. complete at least two one-quarter research rotations or tutorials, or one two-quarter research rotation, tutorial, or research paper, continuing to develop relationships with faculty members who might serve as dissertation adviser or reading committee member;
   c. complete 30 units, including most, if not all, of the required courses listed on the candidacy form;
   d. pass an area qualifying exam;
   e. be advanced to candidacy by the faculty.

3. To maintain good standing in the degree program, third-year students must:
   a. submit a progress form listing the dissertation topic and signed by the dissertation adviser (if the dissertation adviser is not an MS&E faculty member, the form must also be signed by an MS&E faculty member who agrees to be on the student’s reading committee, as well as the student’s point of contact within the department);
   b. complete 30 units, including any remaining depth courses.

4. To maintain good standing in the degree program, fourth-year students must:
   a. select a reading committee (a dissertation adviser and two readers) with at least one member from the student’s major department, and submit the reading committee form signed by each member on the reading committee;
   b. make satisfactory progress on their dissertation as determined by their dissertation adviser;
   c. if the student has not transferred any previous graduate units to Stanford, complete 30 dissertation units.

5. To maintain good standing in the degree program beyond the fourth year, students must make satisfactory progress on their dissertation as determined by their dissertation adviser and approved by the faculty. Indeed, the dissertation adviser will have to present the case to (and seek approval for good standing of the student from) the faculty in the annual faculty meeting for student review. It should be noted that each student inherently has to pass the oral examination (see below) and submit their dissertation before their candidacy expires.

Additionally, to remain in good standing, and to remain eligible for funding, students must perform well in all assistantship positions.

Any special cases, for a student to remain in good standing based on extenuating circumstances, must be presented to and approved by the whole faculty.

Oral Examination
As administered in this department, the University oral examination is a defense of the dissertation; however, the candidate should be prepared to answer any question raised by any members of the Academic Council who choose to be present. The examining committee consists of the three members of the reading committee as well as a fourth faculty member and an orals chair. The chair must be an Academic Council member and may not be affiliated with either the Department of Management Science and Engineering nor any department in which the student’s adviser has a regular appointment; emeriti professors are eligible to serve as orals chair. It is the responsibility of the student’s adviser to find an appropriate orals chair. The University oral examination may be scheduled after the dissertation reading committee has given tentative approval to the dissertation.

The student must be enrolled in the quarter of their oral examination. Students should schedule three hours for the oral examination, which usually consists of a 45-minute public presentation, followed by closed-session questioning of the examinee by the committee, and committee deliberation. The student needs to reserve a room, and meet with the student services manager to complete the oral examination schedule and pick up other paperwork. This paperwork, along with an abstract, needs to be delivered to the orals chair at least one week prior to the oral examination.

Course Requirements
Computational Social Science
The Computational Social Science track teaches students how to apply rigorous statistical and computational methods to address problems in economics, sociology, political science and beyond. The core course work covers fundamental statistical concepts, large-scale computation, and network analysis. Through electives, students can explore topics such as experimental design, algorithmic economics, and machine learning.

Select at least one class from each of four different core areas.

Statistics core:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
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</thead>
<tbody>
<tr>
<td>MS&amp;E 226</td>
<td>Fundamentals of Data Science: Prediction, Inference, Causality</td>
</tr>
<tr>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
</tr>
<tr>
<td>STATS 305A</td>
<td>Applied Statistics I</td>
</tr>
</tbody>
</table>

Computation core:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 231</td>
<td>Introduction to Computational Social Science</td>
</tr>
<tr>
<td>CS 246</td>
<td>Mining Massive Data Sets</td>
</tr>
</tbody>
</table>

Networks core:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 334</td>
<td>Topics in Social Data</td>
</tr>
<tr>
<td>CS 224W</td>
<td>Machine Learning with Graphs</td>
</tr>
</tbody>
</table>

Social Science core:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 241</td>
<td>Economic Analysis</td>
</tr>
<tr>
<td>MS&amp;E 270</td>
<td>Strategy in Technology-Based Companies</td>
</tr>
<tr>
<td>MS&amp;E 280</td>
<td>Organizational Behavior: Evidence in Action</td>
</tr>
<tr>
<td>MS&amp;E 274</td>
<td>Dynamic Entrepreneurial Strategy</td>
</tr>
<tr>
<td>ECON 202N</td>
<td>Microeconomics I For Non-Economics PhDs</td>
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</tbody>
</table>

Computational Social Science track expands students' skills in developing and analyzing data-driven models, as well as understanding how these models impact real-world systems. The core courses provide a strong foundation in statistical methods and computational techniques, while electives allow students to delve into specific areas of interest. The program prepares students for careers in academia, industry, or government, where they can apply their knowledge to solve complex social science problems.
should take place in the Spring Quarter of the student’s second year, or
progress on a regular basis during the two quarters. The presentation
another committee member must be kept informed of the student’s
which case the presentation can be of the two tutorials together, and
The student can do both tutorials with the same faculty member, in
end of these tutorials, the student must make a 45-minute presentation
of one of their tutorials to a committee of three CSS faculty members.

Decision Analysis and Risk Analysis
Prerequisites:

- CS 106A Programming Methodology
- CME 100 Vector Calculus for Engineers
- CME 103 Introduction to Matrix Methods

Required:
- MS&E 201 Dynamic Systems
  or EE 263 Introduction to Linear Dynamical Systems
- MS&E 211 Introduction to Optimization
  or MS&E 211X Introduction to Optimization (Accelerated)
  or MS&E 213 Introduction to Optimization Theory
  or MS&E 311 Optimization
- MS&E 220 Probabilistic Analysis
- MS&E 221 Stochastic Modeling
  or STATS 217 Introduction to Stochastic Processes I
- MS&E 223 Simulation
- MS&E 241 Economic Analysis
- MS&E 250A Engineering Risk Analysis
- MS&E 250B Project Course in Engineering Risk Analysis
  or MS&E 351 Dynamic Programming and Stochastic Control
- MS&E 252 Decision Analysis I: Foundations of Decision Analysis
- MS&E 352 Decision Analysis II: Professional Decision Analysis
- MS&E 353 Decision Analysis III: Frontiers of Decision Analysis
- MS&E 355 Influence Diagrams and Probabilistic Networks

Recommended:
- MS&E 245A Investment Science
- MS&E 254 The Ethical Analyst
- MS&E 270 Strategy in Technology-Based Companies
- MS&E 280 Organizational Behavior: Evidence in Action
- MS&E 321 Stochastic Systems
  or STATS 218 Introduction to Stochastic Processes II
- CS 228 Probabilistic Graphical Models: Principles and Techniques
- CS 270 Modeling Biomedical Systems: Oncology, Terminology, Problem Solving
- ECON 286 Game Theory and Economic Applications
- ECON 290 Multiperson Decision Theory
- STATS 200 Introduction to Statistical Inference
  or STATS 202 Data Mining and Analysis
  or ECON 271 Intermediate Econometrics II

Quantitative Finance
The finance area focuses on the quantitative and statistical study of financial risks, institutions, markets, and technology. Students take courses in probability, statistics, optimization, finance, economics, and computational mathematics as well as a variety of other courses. Recent dissertation topics include studies of machine learning methods for risk
management; systemic financial risk; algorithmic trading; optimal order execution; large-scale portfolio optimization; mortgage markets; and statistical testing of financial models. Ph.D. students in the area typically are affiliated with the Center for Financial and Risk Analytics (CFRA).

Prerequisites (may be waived based on prior coursework)

Mathematics

MATH 113 Linear Algebra and Matrix Theory
MATH 115 Functions of a Real Variable
or MATH 171 Fundamental Concepts of Analysis

Probability

MS&E 220 Probabilistic Analysis
or STATS 116 Theory of Probability
MS&E 221 Stochastic Modeling

Statistics

STATS 110 Statistical Methods in Engineering and the Physical Sciences

Programming

CS 106A Programming Methodology

Economics

MS&E 241 Economic Analysis
or ECON 50 Economic Analysis I

Required Core Courses

Optimization

MS&E 211 Introduction to Optimization
or MS&E 211X Introduction to Optimization (Accelerated)
or MS&E 213 Introduction to Optimization Theory
or MS&E 310 Linear Programming
or MS&E 311 Optimization

Stochastics

MS&E 321 Stochastic Systems
or MS&E 322 Stochastic Calculus and Control

Statistics

STATS 200 Introduction to Statistical Inference
or STATS 305A Applied Statistics I
or STATS 315A Modern Applied Statistics: Learning

Numerical Methods

MS&E 223 Simulation
or CME 200 Linear Algebra with Application to Engineering Computation
or CME 206 Introduction to Numerical Methods for Engineering

Strongly Recommended

STATS 300A Theory of Statistics I
STATS 310A Theory of Probability I

Elective Courses (select at least 4)

MS&E 245A Investment Science
MS&E 245B Advanced Investment Science
MS&E 246 Financial Risk Analytics
MS&E 347 Credit Risk: Modeling and Management
MS&E 348 Optimization of Uncertainty and Applications in Finance
MS&E 349 Financial Statistics
ECON 236 Financial Economics I
ECON 237 Financial Economics II
ECON 273 Advanced Econometrics I
ECON 274 Advanced Econometrics II
ECON 276 Computational Econometrics
FINANCE 625 Empirical Asset Pricing

MATH 238 Mathematical Finance
STATS 231 Statistical Learning Theory
STATS 240 Statistical Methods in Finance
STATS 243 Risk Analytics and Management in Finance and Insurance
STATS 315B Modern Applied Statistics: Data Mining

Students should discuss their course schedule with their dissertation advisers. Other courses in MS&E, Economics, Finance, Scientific Computing, or Statistics at the MS&E 300-level (or comparable in other departments) may be chosen after consulting with the dissertation adviser.

Quantitative Finance Qualifying Procedure

In addition to beginning an appropriate course program, students must pass two quarters of tutorial and an oral examination to obtain qualification. The tutorials emphasize basic research skills. The oral examination emphasizes command of basic concepts as represented in the required courses as well as the modeling of practical situations.

Energy and Environment Policy (see Policy and Strategy)

Health Policy (see Policy and Strategy)

National Security Policy (see Decision Analysis and Risk Analysis)

Operations Management

Foundation courses (may be waived based on prior coursework):

MS&E 211 Introduction to Optimization
or MS&E 211X Introduction to Optimization (Accelerated)
or MS&E 213 Introduction to Optimization Theory
MS&E 241 Economic Analysis
or ECON 202N Microeconomics I For Non-Economics PhDs
MS&E 260 Introduction to Operations Management

Methodology courses (all):

MS&E 221 Stochastic Modeling
or STATS 217 Introduction to Stochastic Processes I
MS&E 223 Simulation
or STATS 362 Topic: Monte Carlo
MS&E 251 Introduction to Stochastic Control with Applications
or MS&E 351 Dynamic Programming and Stochastic Control
MS&E 311 Optimization
or EE 364A Convex Optimization I
MS&E 321 Stochastic Systems

OM research courses (any four):

MS&E 365 Mechanism and Market Design

Faculty-approved GSB OIT Ph.D. courses (about six are offered every two years).

Optimization and Stochastics

Prerequisites:

MS&E 220 Probabilistic Analysis
or STATS 116 Theory of Probability
MS&E 221 Stochastic Modeling
or STATS 217 Introduction to Stochastic Processes I
MS&E 241 Economic Analysis
or ECON 50 Economic Analysis I
CS 106A Programming Methodology
or CS 106X Programming Abstractions
MATH 113 Linear Algebra and Matrix Theory
MATH 115 Functions of a Real Variable
or MATH 171 Fundamental Concepts of Analysis

Strongly Recommended:
In addition to the four core courses, students should take at least four 3-4 unit courses in some coherent area of specialization. The area of specialization may be methodological; examples include (but are not limited to) optimization, stochastic systems, stochastic control, algorithms, economic analysis, statistical inference, scientific computing, etc. The area of specialization could also have a significant modeling and application component, such as (but not limited to) information services, telecommunications, financial engineering, supply chains, health care, energy, etc. Independent of the choice of specialization, students are encouraged to take a range of courses covering methodology, modeling, and applications. Any MS&E courses satisfying this requirement must be at the 300-level, while courses outside MS&E must be at a comparable level. Students are expected to earn a letter grade of A- or better in all courses counted for the requirements. A student’s plan for completing these requirements must be discussed with and approved by their faculty adviser by the beginning of Autumn Quarter of their second year.

**Optimization and Stochastics Qualifying Procedure**

Students take the area qualifying exam at the beginning of their second year of study. The qualifying exam consists of two written exams: one in Optimization and one in Stochastic Systems. The first exam covers the material in MS&E 310 and related prerequisites. The second exam covers the material in MS&E 321 and related prerequisites.

The student does two quarter-length tutorials with Optimization and Stochastics faculty (or affiliated faculty). A written report approved by the supervising faculty member is required on each tutorial. In addition, at the end of the second year, students are expected to make a 30-minute presentation to the broader Optimization and Stochastics faculty. The presentation must include original research or promising directions towards original research. The student can do both tutorials with the same faculty member; in this case a single written report is sufficient, and the presentation can be of the two tutorials together.

**Organizations, Strategy, Innovation, and Entrepreneurship**

Foundation in Organizational Behavior (five courses):
- MS&E 389 Seminar on Organizational Theory

Plus three of the following, which must include at least one 37x course and one 38x course:
- MS&E 370 Current Topics in Strategy, Innovation and Entrepreneurship
- MS&E 371 Innovation and Strategic Change
- MS&E 372 Entrepreneurship Doctoral Research Seminar
- MS&E 376 Strategy Doctoral Research Seminar
- MS&E 383
- MS&E 384 Groups and Teams

Statistics and Research Methods (examples; three courses required)
- MS&E 231 Introduction to Computational Social Science

In their first two years in the Ph.D. program, all students are expected to work with faculty on research. To ensure an early start, all students must work at least 25% of their time in their first year as a research assistant with a faculty member. Students on fellowships can earn course credit for the work. With approval from the students’ adviser, one quarter of the requirement may be fulfilled by working as a Course Assistant (CA).

Ph.D. students in organizational behavior must take 3 courses in statistics and research methods. Two of these courses must be statistics courses.

Ph.D. students are required to take a minimum of 2 advanced-content courses chosen with input from their adviser.

Students are expected to complete a yearly plan, of no more than two typed pages in length, detailing the student's plans for the next year in terms of education (e.g., courses and seminars), research (e.g., RAships), and teaching (e.g., TAships). This plan should be provided to the students' academic adviser for review no later than May 15 each calendar year.

**Policy and Strategy**

The Policy and Strategy (P&S) Area addresses policy and strategy questions in a variety of organizational and societal settings. In order to approach interdisciplinary research questions in application domains as diverse as energy, environment, health, information technology, innovation, and government regulation, P&S faculty members rely on a broad range of analytical and empirical tools, such as decision analysis, optimization and operations research methods, formal economic modeling, econometrics, case studies, and simulation. After having been exposed to foundational knowledge of economics, strategy, and organizational theory, doctoral students in the P&S Area can select from a variety of courses to deepen their understanding of the specific application domains. The P&S Area’s mission is to provide a first-class learning and research environment preparing doctoral students for careers at research universities, government institutions, and in the private sector.

**Foundation in Policy and Strategy (three):**
- MS&E 241 Economic Analysis
- MS&E 376 Strategy Doctoral Research Seminar
- MS&E 390 Doctoral Research Seminar in Health Systems Modeling
- MS&E 391 Doctoral Research Seminar in Energy-Environmental Systems Modeling and Analysis

**Statistics and Research Methods (three):**
- MS&E 201 Dynamic Systems
- MS&E 211 Introduction to Optimization
- MS&E 211X Introduction to Optimization (Accelerated)
- MS&E 213 Introduction to Optimization Theory
- MS&E 212 Mathematical Programming and Combinatorial Optimization
- MS&E 221 Stochastic Programming
- MS&E 223 Simulation

**Management Science and Engineering**
Domain Depth
Research Methods
Sample Program: Risk Analysis Emphasis

- MS&E 350 Decision Analysis II: Professional Decision Analysis
- PSYCH 252 Statistical Methods for Behavioral and Social Sciences
- SOC 383 Sociological Methodology III: Models for Discrete Outcomes
- SOC 384 New Models and Methods in the Social Sciences

The student must select a program of four or more electives including disciplinary depth courses that reflects his or her interests and this approved by the Policy and Strategy faculty.

The following are a number of sample programs:

### Sample Program: Modeling Emphasis

- **Research Methods**
  - MS&E 201 Dynamic Systems
  - MS&E 252 Decision Analysis I: Foundations of Decision Analysis
  - MS&E 311 Optimization
  - MS&E 321 Stochastic Systems

- **Domain Depth**
  - MS&E 292 Health Policy Modeling
  - HRP 392 Analysis of Costs, Risks, and Benefits of Health Care

- **Two of the following:**
  - MS&E 263 Healthcare Operations Management
  - MS&E 463 Healthcare Systems Design
  - HRP 256 Economics of Health and Medical Care
  - HRP 263 Advanced Decision Science Methods and Modeling in Health

### Sample Program: Economics Emphasis

- **Research Methods**
  - ECON 282 Contracts, Information, and Incentives
  - ECON 286 Game Theory and Economic Applications

- **Domain Depth**
  - ECON 257 Industrial Organization 1
  - ECON 285 Matching and Market Design

- **Sample Program: Strategy Emphasis**

- **Research Methods**
  - MS&E 408 Directed Reading and Research (Methods Apprenticeship)
  - SOC 369 Social Network Methods

- **Domain Depth**
  - MS&E 371 Innovation and Strategic Change
  - MS&E 376 Strategy Doctoral Research Seminar
  - SOC 314 Economic Sociology

### Sample Program: Risk Analysis Emphasis

- **Research Methods**
  - MS&E 250A Engineering Risk Analysis
  - MS&E 251 Introduction to Stochastic Control with Applications
  - MS&E 252 Decision Analysis I: Foundations of Decision Analysis
  - MS&E 355 Influence Diagrams and Probabilistics Networks

- **Domain Depth**
  - MS&E 250B Project Course in Engineering Risk Analysis
  - MS&E 353 Decision Analysis III: Frontiers of Decision Analysis

Students are expected to complete a yearly plan, of no more than two typed pages in length, detailing the student’s plans for the next year in terms of education (e.g., courses and seminars), research (e.g., RAships), and teaching (e.g., TAships). This plan should be provided to the students’ academic adviser for review no later than May 15 each calendar year.

### Policy and Strategy Qualifying Procedure

Advancement to Ph.D. candidacy is determined at the end of the student’s second year of studies, based on the following three components:

1. the student’s overall grade point average in the program (a GPA of 3.5 or higher is required);
2. a second-year research paper that is written by the student under the supervision of a faculty member, and that is presented to examining faculty members in the second year;
3. a written and an oral qualifying examination taken by the student in the spring quarter of the second year.

### Ph.D. Minor in Management Science and Engineering

Students pursuing a Ph.D. in another department who wish to receive a Ph.D. minor in Management Science and Engineering should consult the MS&E student services office. A minor in MS&E may be obtained by completing 20 units of approved graduate-level MS&E courses, of which at least 6 units must be at the 300-level. Courses approved for the minor must form a coherent program, and include a breadth of courses from across the department. The program must include a minimum of 16 letter-graded units, and a minimum grade point average of 3.3 must be achieved in these courses.

### Graduate Advising Expectations

The Department of Management Science and Engineering is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Every student is assigned a faculty program adviser based on their stated area within the department. Faculty program advisers guide all students in key areas such as selecting courses, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. Faculty program advisers additionally guide doctoral students in designing and conducting research, and development of teaching pedagogy. Faculty program advisers and students meet regularly, and the faculty program adviser may initiate a meeting with any student deemed to be in academic or research distress.

Doctoral students are encouraged to explore research activities in several research groups/labs during their first academic year, and to declare candidacy with a faculty dissertation adviser by the end of their second year in the program. Students may align with faculty across the department. This faculty dissertation adviser supersedes the faculty program adviser in assuming primary responsibility for advising and mentoring the student. When the faculty dissertation adviser is from outside our department, the student must also identify a faculty research adviser from MS&E to provide guidance on departmental requirements, core coursework, and opportunities. We encourage students to decide on their thesis committee within one year after start of candidacy in order to avail themselves of advice from multiple faculty members on the reading committee. MS&E conducts an annual review of all doctoral students’ progress on degree progress milestones and research. Research input is
solicited and an individual progress report spelling out the forthcoming
milestones and any remedial action needed to maintain status is sent to
the student via email.

Master students are encouraged to explore courses from across the
department, and with multiple MS&E faculty members. Students may
request a new adviser from MS&E Student Services staff as their
interests clarify. Master's students are encouraged to meet with their
adviser on a regular basis, to discuss their program goals and objectives,
course selection, career goals, and academic and industry opportunities.

The MS&E student services staff are also an important part of the
advising team. They inform students and advisers about University and
department requirements, procedures, opportunities, and maintain the
official records of adviser assignments and course approvals. Students
are encouraged to talk with both the faculty program adviser and the
student services office as they consider courses.

Students are active contributors to the advising relationship and we
urge them to proactively seek academic and professional guidance
and take responsibility for informing themselves of policies and degree
requirements for their graduate program. We therefore expect students
to read regular communication from the Registrar's office and Student
Services regarding upcoming academic deadlines and policy updates,
and to be responsible for complying with the university and program
requirements.

For a statement of University policy on graduate advising, see
the "Graduate Advising (http://exploredegrees.stanford.edu/
gratedegrees/#advisingandcredentialstext)" section of this bulletin.

Emeriti: (Professors) James L. Adams, Stephen R. Barley, Richard W.
Cottle, B. Curtis Eaves, Warren H. Hausman, Frederick S. Hillier, Ronald
A. Howard, Donald L. Iglehart, David G. Luenberger, Michael M. May,
William J. Perry, David A. Thompson; (Associate Professor) Samuel S.
Chiu; (Professors, Research) Siegfried S. Hecker, Walter Murray, Michael A.
Saunders; (Professor, Teaching) Robert E. McGinn

Chair: Nicholas Bambos

Director of Graduate Studies: Kay Giesecke

Director of Undergraduate Studies: Ross D. Shachter

Professors: Nicholas Bambos, Margaret L. Brandeau, Kathleen M.
Eisenhardt, Kay Giesecke, Peter W. Glynn, Ashish Goel, Pamela J. Hinds,
Ramesh Johari, Riitta Katila, M. Elisabeth Paté-Cornell, Robert I. Sutton,
James L. Sweeney, Benjamin Van Roy, Yinyu Ye

Associate Professors: Itai Ashlagi, Jose Blanchet, Charles E. Eesley, Amin
Saberi, Ross D. Shachter, Edison T. S. Tse

Assistant Professors: Guillaume W. Basse, Sharad Goel, Irene Y. Lo, Markus
Pelger, Aaron Sidford, Johan Ugander, Melissa A. Valentine

Professor (Research): John P. Weyant

Professor (Teaching): Thomas H. Byers

Professor of the Practice: Tina L. Seelig

Courtesy Professors: Stephen P. Boyd, Paul Milgrom, Douglas K. Owens,
Alvin Roth