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**IMPORTANT NOTE:**

The primary purpose of the handbook is to provide information specific to the OR&E major. Information about Cornell University and Engineering College guidelines for graduation and honors are provided here for reference only. You are responsible for checking College and University documentation for rules and regulations not specific to the OR&E major.

**STUDENT RESPONSIBILITIES FOR MEETING DEGREE REQUIREMENTS:**

Ultimately, it is your responsibility to understand the degree requirements for the major and to plan your course of study accordingly. You should consult the ORIE undergraduate major office (203 Rhodes) for specific information relating to the fulfillment of degree requirements. Your faculty advisor will assist you in course selection, but it is your responsibility to ensure that the courses you select will fulfill degree requirements.

Updated October 2019

## **OR&IE AT CORNELL**

### **Introduction**

This handbook has been designed to inform you about the School of Operations Research and Information Engineering (OR&IE) at Cornell. It will help you gain an understanding of the major program, the courses, the faculty and staff, various procedures, career opportunities, graduate studies, and student activities. This handbook, together with consultations with your faculty advisor, should provide you with the information you need concerning the Operations Research Engineering major.

The faculty and staff welcome you to the School. We look forward to getting to know you and are confident that you will have a challenging and rewarding educational experience.

### **What Operations Research Engineering Is About**

The operations research engineering undergraduate major will give you a broad understanding of the techniques and modeling concepts needed to analyze and design complex systems. As an operations researcher, you'll make many decisions that involve the interplay of people, time, money, energy and materials. All business systems are complex and need sophisticated decision-making methods that enable employees and the equipment they operate to perform most efficiently. The allocation of resources may be represented and analyzed mathematically. Specialists in operations research engineering use a variety of mathematical techniques and specialized computing tools to develop and apply techniques to get the most out of valuable resources.

An automobile manufacturer, for example, might be able to save millions of dollars a year by identifying and eliminating bottlenecks in an assembly line. If an airline improves its ability to forecast passenger demand, and adjusts its schedules accordingly, more seats may be filled. If a hospital schedules the use of its operating rooms more efficiently, costs may be reduced improving service to patients. These are the types of problems that may be solved by experts in operations research and engineering. As work becomes technologically more complex and the demands of the economy require a more efficient use of resources, a growing number of specialists in this field will be needed.

### **Employment Opportunities**

Historically, the field of operations research engineering has been concerned with manufacturing and the delivery of goods and services, and many operations researchers continue to find opportunities in those areas. In recent years, however, the field has expanded as business and industry have recognized that the methods of operations research and engineering may also be used profitably in fields like finance and information technology. As a result, you'll likely find ORE graduates working as investment bankers and in information technology offices, as well as consultants, analysts, industrial engineers and managers in a wide variety of areas. The major provides analytical tools that will allow you to seek flexible career pathways.

Below are some career choices of recent ORE graduates:

- Accenture, Technology Consultant
- Amazon, Operations Manager
- Barclays, Rates Trading
- Capital One, Financial Analyst
- Deloitte Consulting, Business Technology Analyst
- ExxonMobil, Industrial Engineer
- Johnson & Johnson, Information Technology Leadership Development
- J.P. Morgan Chase & Co., Business Analyst
- Microsoft, Software Developer
- Proctor & Gamble, Supply Chain Operations Manager

## History of the School

Cornell's educational contributions to our discipline reach back almost to its beginning. In the 1890's, Frederick Taylor introduced ideas for improving the efficiency of labor by breaking down the steps required for a task and designing "the one best method" for all steps and the task they comprise. When Taylor presented a paper, "Shop Management," at the 1903 meeting of the American Society of Mechanical Engineers, Dexter Kimball, then works manager at Stanley Electric Manufacturing Company, later the first Dean of the College of Engineering at Cornell, was in the audience. By 1905 Kimball was teaching about the economics of production at Cornell. In 1913, Kimball wrote in *Principles of Industrial Organization*, "the application of these well-known methods .... has become known as efficiency engineering, industrial engineering, or scientific management." Since that time, many other terms have been linked to the discipline(s) that grew from this approach, among them: *administrative science*, *administrative engineering*, *systems analysis*, *systems engineering*, *management science*, *engineering management*, *management engineering*, *operations management*, *operations research*. One could debate whether these terms are all variations on a theme, or whether they represent distinct descendants of a common ancestor. Their standard short definitions are very similar – application of *scientific methods* to *systems* in order to design and operate them *efficiently*. They might diverge only when the succinct definitions were expanded to include shades of emphasis and delineations of both methods and application areas.

The designation *operations research* first emerged during World War II in England. Military planners worked with civilians from a variety of disciplines, including mathematics and engineering, to tackle the challenges imposed by the logistical support of massive military operations. Operations Analysis (or, Operational Analysis, in British English) was the name that was initially associated with their systematic approach to planning and with the collection of mathematical tools employed. Over time, it came to be called Operations Research.

Even within Cornell, the name of the academic unit tasked with teaching industrial engineering and its namesakes has changed several times to reflect changes in emphasis within the unit at Cornell, as well as changes in perspective within the broader professional community: administrative engineering, industrial engineering, operations research and information engineering have all appeared in the name of our unit at various times. It was part of the Sibley School of Mechanical Engineering until the 1960's, when a separate unit was created, which (eventually) became the School of OR&IE. For decades, OR&IE stood for Operations Research and Industrial Engineering; it now decodes as Operations Research and Information Engineering.

Why the change in 2006 to Operations Research and *Information Engineering*? The ongoing information revolution has dramatically broadened the impact of OR. Information Engineering, the process of transforming data into useful information, has always played a key role in OR, but the rapidly increasing scope and scale of available data challenges us to better understand this process. The role of information is further highlighted by the transformation of the US economy from one based primarily on manufacturing to one oriented towards service industries, where information itself is often a key commodity. The names of courses recently introduced in OR&IE – "Revenue Optimization and Marketplace Design", "Statistical Data Mining", "Service System Modeling and Design", and "Learning with Big Messy Data" – reveal how the School's mission is expanding in this direction.

The current OR&IE faculty has carried forward the strong traditions established a by an earlier generation, building more powerful mathematical foundations, developing faster more robust methods, and expanding greatly the scope of applications. OR is a multidisciplinary field, and, a natural outcome of the new initiatives in such application areas as data mining, information technology, financial engineering, and supply chain management has been a trend toward work that synthesizes diverse methods.

In teaching, as in research, OR&IE at Cornell has put a premium on mathematical rigor, pushing the envelope, not merely knowing what works and what doesn't, but also understanding why it works or doesn't. Armed with such training, graduates of the ORE major are typically able to make broader, more fundamental contributions to the practice of OR. They are able to adapt to the ever more rapidly changing workplace, where tools that work today may be based on assumptions that won't hold tomorrow.

## PERSONNEL

### Faculty

Among faculties in operations research and the related disciplines (industrial engineering, systems engineering, engineering management, etc.), Cornell's faculty is among the most distinguished.

### Name

### Area(s) of Teaching and Research

Siddhartha Banerjee, Asst. Prof.	Stochastic Modeling, Game Theory, Network Algorithms
Kathryn Caggiano, Prof. of Practice, Dir. MEng	Supply Chain Management
John R. Callister, Senior Lecturer	Entrepreneurship, Economic Analysis
Yudong Chen, Asst. Prof.	Machine Learning, Convex Optimization
Damek Davis, Asst. Prof.	Optimization, Algorithms
Jim Dai, Prof.	Performance Analysis, Stochastic Processing Networks
Dietrich Brenda, Prof. of Practice	Mathematical Optimization, Resource Allocation
Peter Frazier, Assoc. Prof.	Statistical Learning
David Goldberg, Assoc. Prof.	Inventory Models, Queueing Theory, Prob. & Stoch. Proc.
Shane G. Henderson, Prof.	Applied Prob., Financial Engr., Info. Tech. Modeling
Christina Lee Yu, Asst. Prof.	Statistics, Scalable Algorithms
Adrian S. Lewis, Prof.	Optimization, Algorithms
Mark E. Lewis, Prof. and Director	Applied Prob., Financial Engr., Supply Chain Mgt.
Andreea Minca, Assoc. Prof.	Mathematical Modeling
Pierre Patie, Assoc. Prof.	Probability Theory, Financial & Insurance Mathematics
Jamol Pender, Asst. Prof.	Queueing Theory, Applied Probability, Markov Processes
James Renegar, Prof., Dir. Undergraduate	Optimization, Algorithms
David Ruppert, Prof.	Statistics, Data Mining, Financial Engineering
Gennady Samorodnitsky, Prof., Dir. Graduate	Applied Probability, Financial Engr., Statistics
Katya Scheinberg, Prof.	Optimization, Algorithms
David B. Shmoys, Prof.	Optimization, Algorithms, Supply Chain Mgt.
Madeleine Udell, Asst. Prof.	Optimization and Machine Learning
David P. Williamson, Prof.	Optimization, Algorithms, Info. Tech. Modeling

### **Support Staff**

You may also have occasion to interact with some of the support staff of the School, including:

Heidi Russell (hjr27)	Undergraduate Services Coordinator	203 Rhodes Hall
Katrina Overton (kmo12)	Graduate Services Coordinator	201 Rhodes Hall
Tara Woodard (tlb17)	ORIE Main Office	206 Rhodes Hall

Heidi Russell is responsible for tracking your progress through the School and may answer your questions about the administrative aspects of the undergraduate program.

## **CURRICULUM**

### **Description of the ORE Curriculum & Graduation Requirements**

The curriculum for the B.S. degree with a major in Operations Research Engineering is summarized on the curriculum checklist at the end of this Handbook. When all the courses listed are completed successfully, and the student's cumulative GPA is at least 2.0, and the student's Major GPA is at least 2.0, the degree will be awarded. The Major GPA includes distribution courses (3 courses), ORIE required major courses (8 courses) and ORIE electives (3 courses). ENGRD 2700 and MATH 2940 must be completed with a C or better. All other MATH courses, ENGRD 2110, and ORIE required major courses must be completed with a C- or better to receive credit.

For each student, an updated copy of the checklist is kept in Room 203, Rhodes Hall. Each student should obtain a copy of his/her checklist and keep his/her own record of progress. Detailed comments on each section of the form follow.

### **Required Engineering Core Courses**

ORE affiliates are required to complete Math 1910, 1920 and 2940. Either Math 2930, Math 3040 or CS 2800 may be used to satisfy the fourth mathematics requirement. Students should discuss with their advisor which of these three courses is most appropriate to their future program of study. Chemistry 2080, Math 2930 (if not used to meet the mathematics requirement), CS 2800 (if not used to meet the mathematics requirement), Math 3040 (if not used to meet the mathematics requirement), Math 3110 or Math 3360 may be taken in place of Physics 2214. Students who do not take Math 2930 may not enroll in Physics 2214 (Math 2930 is a pre-requisite for Physics 2214) and should plan to enroll in one of the alternative courses.

ORE affiliates must receive at least a C in MATH 2940. Each remaining course in mathematics used to fulfill a core requirement must be passed with a grade of at least "C-". If this grade level is not achieved, the course must be repeated.

### **Engineering Distribution Courses**

The most suitable Introduction to Engineering course for ORE majors is ENGRI 1101. ENGRD/CS 2110 is required of all ORE majors and must be passed with a grade of C- or better before the end of the sixth semester. If this grade level is not achieved, the course must be repeated. ENGRD/CS 2110 may be taken as a distribution course or major approved elective. ENGRD 2700 is a required distribution course and must be passed with a grade of C or better.

## **Required Major Courses**

The following courses are required of all ORE majors:

ORIE 3120, 3150\*, 3300, 3310, 3500, 3510, 4580, organizational behavior course\*\*.

Each ORIE required major course must be passed with a grade of C- or better. If this requirement is not met the first time a course is taken, the course must be repeated within one year and a satisfactory grade attained before the next course in the sequence (ORIE 3310 and ORIE 3510 in particular) may be taken. Failure to achieve at least a C- the second time will generally result in withdrawal from the program. Courses taken a second time in order to meet this requirement do not yield additional credit toward the degree. Transfer credit will not be granted for required major courses except for (1) transfer students who took an equivalent course at another institution prior to enrollment at Cornell, and (2) students formally enrolled in Cornell's "Study Abroad" program.

\*Students are allowed to replace the requirement for ORIE 3150 (Financial and Managerial Accounting) by taking at least one of:

- MATH 3110 (Introduction to Analysis)
- MATH 4130 (Honors Real Analysis)
- MATH 4310 (Linear Algebra)
- MATH 4330 (Honors Linear Algebra)
- Any 6000 level ORIE course

If a course is used to replace this requirement, then it cannot also be used as an advisor approved, major approved, or ORIE elective.

\*\*For the Classes of 2020 and 2021, the Organizational Behavior course may be replaced with an additional 3 credits in Major Approved Electives, from either category A or B. If students do not take an Organizational Behavior course, Major Approved Electives will require 12 credits with at least 6 credits from the A category, and at least 6 credits (out of the 12) must be from outside of ORIE. The College requires at least 9 credits of the major program be outside of ORIE. Those credits are CS 2110 and 6 credits of Major Approved Electives outside of ORIE.

\*\*The Class 2022 has no Organizational Behavior requirement. They must complete at least 9 credits of major approved electives. At least 6 credits must be from the A category and at least 6 credits must be from outside of ORIE.

\*\*The Class of 2023 will complete 12 credits of Major Approved electives with at least 6 credits from the A category, and at least 6 credits (out of the 12) must be from outside of ORIE. (No Organizational Behavior course.)

\*\*The Organizational Behavior requirement is satisfied by any one of the following 3 credit hour courses: ENGR 3350, ILR 1220, ILRID 1700, ILRHR 2600, NCC 5540, AEM 3245, NBA 6630, and HADM 1150, HADM 4160.

\*\*NBA 6660, NBA 6700, NBA 6710, NBA 6820 and NBA 6830 (all 1.5 credits) are also approved to fulfill the organizational behavior requirement. ORE majors may take any 2 of these courses for a combination of 3 credits total. However, students MAY NOT enroll in NBA 6660 AND NBA 6820 to fulfill the requirement due to content overlap. That is the only exception in the combination of courses. All courses listed are offered at the discretion of the fields and are not always offered every term.

**ORIE Electives (9 credits)**

Any non-required ORIE course at the 4000 level or higher, as well as ORIE 3800, counts as an ORIE elective, except not ORIE 4152, 9000, 9100 and 9101.

ORIE 4990 (Teaching in ORIE) may be counted as an ORIE elective (maximum of 3 credits).

Students must be in good academic standing to enroll in ORIE 4999 (Independent Study). Up to 3 credits of ORIE 4999 may be used as an ORIE elective.

Excess credits for ORIE Electives can be applied to Major-Approved Electives. For example, if a student takes three courses to fulfill the 9 credits required for ORIE Electives, and if the courses are worth 4, 4 and 3 credits, then the 2 excess credits can be applied towards Major-Approved Electives (Category A).

**Major-Approved Electives**

All Major-Approved electives must be technical courses numbered 2000 or above. "Technical" means that in a significant part of the course students actively use their skills in mathematics, the sciences, or engineering design in homework or projects. 9 hours of major approved electives are required\*\* (see next paragraph). At least 3 hours must be outside of ORIE, so that with CS 2110 and the behavioral science elective at least 9 hours of the major program are outside of ORIE. Major-approved Electives are categorized into Category A (Engineering, Science, and Mathematics) and Category B (Engineering Design, Finance, and Economic Analysis). At least 6 credits must be in Category A.

\*\*As explained on page 8, for the Classes of 2020 and 2021, the Organizational Behavior course may be replaced with an additional 3 credits in Major-Approved Electives, from either category A or B. If students do not take an Organizational Behavior course, Major Approved Electives will require 12 credits with at least 6 credits from the A category and at least 6 credits outside of ORIE. The College requires at least 9 credits of the major program be outside of ORIE. Those credits are CS 2110 and 6 credits of Major Approved Electives outside of ORIE.

Up to 3 credits from CS 4999 can be counted towards Major-Approved Electives (Category A), but none towards ORIE Electives.

Up to a total of 6 credits from ORIE 4990, ORIE 4999 and CS 4999 may be counted towards ORIE Electives and Major-Approved Electives (where they are in Category A). For example, a student can count 3 credits of ORIE 4990 towards ORIE Electives and another 3 credits of ORIE 4990 towards Major-Approved Electives (but then no credits from ORIE 4999 or CS 4999 can be counted towards either ORIE Electives or Major-Approved Electives).

Below are lists of popular courses that may be used as major-approved electives. Students may petition for other courses to be allowed. Petitions go to the Associate Director for Undergraduates who, with the Academic Standards Committee, will determine if the course meets the definition of "technical" and whether the course is in category A or B. A petition must be accompanied by a syllabus of the course indicating the textbooks used and types of assignments that will be given.

Following are courses that MAY be used as major-approved electives in **Category A** (Engineering, Science, and Mathematics):

AEM 4110 (Introduction to Econometrics) (but not with Econ 3140)

AEP 4210 (Mathematical Physics I)

ASTRO 3340 (Symbolic and Numerical Computing)

BEE 2220 (Bioengineering Thermodynamics and Kinetics)

BIOMG 3300 (Principles of Biochemistry)

BIOMG 3310 (Principles of Biochemistry: Proteins and Metabolism)

BIOMG 3320 (Principles of Biochemistry: Molecular Biology)

BTRY 4270 (Survival Analysis)



BTRY 4381 (Biomedical Data Mining and Modeling)  
 CHEM 2080 (General Chemistry II)  
 CHEM courses with CHEM 2080 or 2160 as a prerequisite  
 EAS 3420 (Atmospheric Dynamics)  
 EAS 4840 (Inverse Methods in the Natural Sciences)  
 ECE 4450 (Computer Networks and Telecommunications)  
 ECE 3530 (Introduction to Systems and Synthetic Biology)  
 ECON 3140 (Introduction to Econometrics, but not with AEM 4110) ECON 3120 is not approved.  
 ECON 3810 (Decision Theory)  
 All MATH courses numbered 3000 or above EXCEPT 4030, 4080, 4710, 4720 and 4740  
 All PHYSICS courses with Physics 2213 or 2214 as a prerequisite  
 All ENGRD Courses (except ENGRD 2700 which must be used in the Distribution Category.)  
 CEE 4630 (Future Transportation Technologies and Systems)  
 CEE 5980 (Intro to Decision Analysis)  
 CEE 6230 (Environmental Quality Systems Analysis)  
 All CS courses with CS 2110 as a prerequisite  
 CS 2770 (Computational Sustainability)  
 CS 2800 (Discrete Structures)  
 CS 3420 (Embedded Systems)  
 CS 4450 (Introduction to Computer Networks)  
 CS 4810 (Intro to Theory of Computing)  
 CS 4852 (Networks II) (CS 2850, Networks, is NOT a Major Approved elective).  
 CS 4999 (up to 3 credits, but see the preceding discussion)  
 CS 5722 (Heuristic Methods for Optimization)  
 INFO 2950 (Introduction to Data Science)  
 MAE 3100 (Intro. to Applied Math)  
 MAE 4860 (Automotive Engineering)  
 MAE 5790 (Nonlinear Dynamics and Chaos)  
 PSYCH 4760 (Quantitative Methods 2)  
 PAM 3100 (Multiple Regression Analysis)  
 PAM 5690 (Regression Analysis and Managerial Forecasting)  
 STSCI 3100 (Statistical Sampling)  
 STSCI 4030 (Linear Models with Matrices)  
 STSCI 4140 (Applied Design)  
 SYSEN 5300 (SysEng and Six Sigma for the Design and Operation of Reliable Systems)  
 All ORIE courses numbered 3000 or above EXCEPT 4152, 9000, 9100, 9101 and 9110  
 For ORIE 4990 and ORIE 4999, see preceding discussion

Courses that MAY be used as major-approved electives in **Category B** (Engineering Design, Finance, and Economic Analysis):

AEM 3100 (Business Statistics)  
 AEM 3390 (Research Methods in International Development)  
 AEM 4060 (Risk Simulation and Monte Carlo Methods)  
 AEM 4160 (Strategic Pricing)  
 AEM 4210 (Futures, Options and Financial Derivatives)  
 AEM 4230 (Topics in Behavioral Finance)  
 AEM 4260 (Fixed Income Securities)  
 AEM 4280 (Valuation of Capital Investment)  
 AEM 4290 (International Financial Management)  
 AEM 4380 (Entrepreneurial Strategy for Technology Ventures)  
 AEM 4390 (Technology Strategy)  
 AEM 4410 (Marketing Research)  
 AEM 4610 (Business Processes, Analytics and Enterprise Systems)  
 AEM 4615 (Digital Platform Strategy)  
 AEM 4660 (Market Dynamics, Computer Simulation and Modeling)  
 AEM 4670 (Investments)  
 BEE 3299 (Sustainable Development)  
 BEE 4010 (Renewable Energy Systems)

BEE 4890 (Entrepreneurial Management for Engineers)  
 ECON 4220 (Financial Economics)  
 ECON 4610 (Industrial Organization I)  
 ECON 4620 (Industrial Organization II)  
 ECON 4903 (Quantitative Analysis of Economic Data)  
 CEE 3610 (Introduction to Transportation Engineering)  
 CEE 4530 (Research in Environmental Engineering)  
 CEE 4640 (Transportation Systems Design)  
 CEE 5900 (Project Management)  
 CEE 5970 (Risk Analysis and Management)  
 CS/INFO 2300 (Intermediate Web Design)  
 INFO 3300 (Data-Driven Web Applications)  
 INFO 3350 (Text Mining History and Literature)  
 INFO 4120 (Ubiquitous Computing)  
 ORIE 4152/ENGRG 4610 (Entrepreneurship for Engineers)  
 HADM 3430 (Marketing Research)  
 HADM 4410 (Strategic Management)  
 MAE 2250 (Mechanical Synthesis)  
 NBA 4120 (Equity Investment Research and Analysis)  
 NBA 5060 (Financial Statement Analysis)  
 NBA 5380 (The Business Idea Factory) 1.5 cr.  
 NBA 5061 (Comprehensive Financial Statement Analysis)  
 NBA 5410 (Project Management)  
 NBA 5420 (Investments and Portfolio Analysis)  
 NBA 5550 (Fixed Income Securities and Interest Rate Derivatives)  
 NBA 6200 (Marketing Research)  
 NBA 6730 (Intro. to Derivatives, Part 1)  
 NBA 6740 (Intro. to Derivatives, Part 2)  
 NBA 6930 (Strategy and Tactics of Pricing)  
 NBA 6940 (Equity derivatives and related products)  
 "Team" courses such as MAE 4250 (FSAE Auto Design) may be used for a total of 3 credits of major approved electives in Category B.

### **Advisor Approved Electives (6 credits)**

Any course mutually agreed upon by a student and his/her advisor may be included in this category. Advisors approve courses in this category if the course is considered to be relevant to the student's educational objectives. For each such course, the advisor signs a form illustrated on page 29. These forms are available in Room 203, Rhodes Hall.

### **Liberal Studies Distribution** (College Requirement)

A minimum of six courses (totaling at least 18 credits) is required and should be chosen with as much care and foresight as courses from technical areas. The courses must satisfy various requirements – see the Engineering Undergraduate Handbook for details.

### **Physical Education** (University Requirement)

In addition to the two semesters of Physical Education, a swimming test must be passed.

### **The Technical Communication Requirement** (College Requirement)

The College of Engineering specifies certain courses as satisfying the technical communication requirement (Google "Cornell engineering technical communication requirement" for details).

Some of the courses can be used to simultaneously satisfy one additional Major requirement or College requirement (but never more than one additional requirement). In particular, any of the courses satisfying the

technical communication requirement and listed as an OR&E Major-Approved elective can simultaneously count towards both requirements. The College allows some of the communication courses to simultaneously count towards Liberal Studies category CE.

### **ROTC Courses**

ROTC courses do not count toward the degree unless co-listed by some other department, in which case the co-listing determines how the course may be used.

### **Supplementary Courses, ENGRG 1050 and Academic Excellence Workshop Credit**

Supplementary courses starting with the digit "0", such as Chemistry 0111, the Engineering Seminar (ENGRG 1050), and Academic Excellence Workshop credit (ENGRG 1920, etc) do NOT count toward the degree.

### **Junior and Senior Year Courses**

The following is a typical junior year schedule for an Operations Research and Engineering major who has completed ENGRD 2700, CS 2110, Math 2940 and ORIE 3120.

#### **Fall Semester**

ORIE 3300 Optimization I  
 ORIE 3500 Probability & Statistics II  
 ORIE 3150 Accounting (or replacement)  
 Approved/Major-approved Elective  
 Liberal Elective

#### **Spring Semester**

ORIE 3310 Optimization II  
 ORIE 3510 Stochastic Processes  
 Behavioral Science/Major-approved elective  
 Approved/Major-approved Elective  
 Liberal Elective

In the Fall Semester of the senior year, ORIE 4580 must be taken. The rest of the schedule in the senior year will consist of the various types of electives necessary to complete degree requirements.

Excess credit hours beyond the minimum required in the various categories may be applied to the Advisor Approved Elective category, subject to the approval of the student's academic advisor.

The minimum course load required to be considered a full-time student is 12 credit hours in each semester, except in the student's final semester. In the final semester, the minimum course load is simply the number of credit hours required to complete degree requirements.

### **Honors Program**

**Eligibility:** To be eligible for the ORE honors program, a student must achieve and sustain a cumulative GPA of at least 3.5, both overall and in the major program.

**Timing:** A student must apply for and be admitted to the honors program no later than the beginning of his or her penultimate semester, i.e., the student must be in the program for at least two semesters prior to graduation. Students may apply for and be admitted to the program as early as the first semester of their junior year.

**Procedures:** Each applicant to the ORE honors program must have a faculty advisor to supervise that student's individual program. This honors advisor need not be the student's faculty advisor. The application to the program shall be a letter from the student describing the specific proposed honors program and including the explicit approval of the honors advisor. Each program must be approved by the Associate Director, and any changes to the student's program must also be approved by the Associate Director.

An ORE honors program shall consist of at least nine credits beyond the minimum required for graduation in ORE, so that no part of the honors program may also be used to satisfy graduation requirements. The nine credits shall be from one or more of the following three categories with at least four hours in category 1:

1. Advanced courses in ORIE at the 5000 level or above.

2. A significant research experience or honors project under the direct supervision of an ORIE faculty member using ORIE 4999 -- ORIE Project. A significant written report must be submitted as part of this component.
3. A significant teaching experience under the direct supervision of a faculty member in ORIE 4990: Teaching in ORIE.

Up to a total of 3 credits from ORIE 4990 and ORIE 4999 can be counted towards the 9 additional credits required for the honors program. These 3 credits are in addition to the 6 credits allowed to count towards ORIE Electives and Major-Approved Electives.

No research, independent study, or teaching for which the student is paid may be counted toward the honors program.

### **Preparing for Ph.D. Programs**

Pursuing a Ph.D. in Operations Research is an exciting, rewarding, and challenging experience. The OR&E major at Cornell can be tailored to prepare students for rigorous Ph.D. programs in Operations Research.

Beyond classes, our department offers many opportunities to prepare for a Ph.D. program and to become a more competitive applicant. We encourage students to start by discussing their interest in graduate programs with their advisor and other faculty in the department. Due to the rigor of Ph.D. programs, we also suggest students to take electives that strengthen their mathematical background; several of these are suggested below. Students interested in Ph.D. programs might also discuss on- and off-campus research opportunities with our faculty. Additional advice may also be found on the OR&E website.

Ph.D. programs in Operations Research generally assume mathematical maturity and the ability to read and write sophisticated mathematical arguments (proofs). Taking at least three of following courses is highly recommended as preparation for Ph.D. programs (especially a course in analysis (Math 3110 or Math 4130), and a course in theoretical linear algebra (Math 4310 or Math 4330)):

CS 2800\* Discrete Structures  
 CS 4820 Introduction to analysis of algorithms  
 CS 4850 Mathematical foundations for the information age  
 Math 3040\* Prove it!  
 Math 3110\*\* Introduction to analysis  
 Math 3360 Applicable algebra  
 Math 4130\*\* Honors introduction to analysis I  
 Math 4310\*\* Linear algebra  
 Math 4330\*\* Honors linear algebra

\* These courses can fulfil the fourth engineering math requirement and/or be substituted for Physics 2214

\*\* Only one of Math 4310 and 4330 can be taken for credit, and only one of Math 3110 and 4130 can be taken for credit

The following electives build on core topics in Operations Research. Taking a few electives in an area you're excited about builds depth and experience.

ORIE 4320 Nonlinear optimization  
 ORIE 4330 Discrete models  
 ORIE 4520 Introduction to stochastic processes II (stochastics at scale)  
 ORIE 4741 Learning with Big Messy Data  
 ORIE 6XXX Ph.D. courses  
 CS 3220 Introduction to scientific computing  
 Math 4410 Introduction to combinatorics I  
 Math 4710 Basic Probability  
 Math 4720 Statistics

The following course entails working on an independent project in Operations Research, and can be used to delve into academic research.

ORIE 4999 ORIE Project

**Preparing for Ph.D. Programs: Sample Courses**

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 4
CHEM 2090	PHYS 1112	PHYS 2213	CS 2800	ORIE 3300	ORIE 3310	MATH 4330	ORIE 4330
MATH 1910	MATH 1920	MATH 2940	MATH 3040	ORIE 3500	ORIE 3510	ORIE 4999	ORIE 4320
ENGR 1101	CS 111x	ENGRD 2700	ORIE 3120	ORIE 3150	Behavioral Science	ORIE 4580	MATH 4410
First-Year Writing Seminar	First-Year Writing Seminar	ENGRD 2110		MATH 4130		CS 4820	ORIE 4741
PE	PE	Liberal Studies	Liberal Studies	Liberal Studies	Liberal Studies	Liberal Studies	Liberal Studies

More information and advice about how to best use the undergraduate curriculum to prepare for competitive Ph.D. programs can be found on the ORIE website and by speaking with your advisor.

**POLICIES AND PROCEDURES**

To maintain fair and uniform academic standards, the School has adopted the following policies and procedures to govern course registration and academic credit. The Associate Director of Undergraduate Studies, Prof. James Renegar, and the Major Coordinator, Heidi Russell are responsible for most administrative aspects of the undergraduate curriculum.

**Requirements for Affiliation**

Students apply for affiliation at the end of the first semester of their sophomore year by visiting the Undergraduate Office in 203 Rhodes Hall. Requirements for ORE affiliation are: at least C in each of MATH 2940 and ENGRD 2700; GPA  $\geq$  2.2 in math, science, and engineering courses (both overall and in the term immediately before affiliation); at least C- in all ORIE courses completed thus far. Good academic standing in the College of Engineering.

**Advising**

Advisors are assigned when a student is affiliated with the major. Students normally continue with this advisor through graduation.

Your advisor serves as a source of information on academic matters. These include: checking requirements, choosing elective courses, and advice on career planning and graduate schools. The approval of your assigned advisor is required on advisor approved elective forms and all petition forms.

You are encouraged to consult with other members of the faculty as well. One reason for getting acquainted with the faculty is that they act as references for jobs and graduate schools.

### **Good Standing Status**

Scholastic requirements are:

1. A cumulative grade point average of at least 2.0.
2. A cumulative grade point average of at least 2.0 in required ORIE courses.
3. At least C- in all Operations Research courses, and by the end of the sixth semester, a grade of at least C- in ENGRD 2110.
4. Satisfactory progress - a minimum of 12 credit hours per semester.
5. No failures or incompletes.

Students who fail to achieve good standing status may be warned, suspended for one or more terms, or denied permission to re-register in the major. The specific action in each case will be based upon the pertinent circumstances as well as the student's previous record.

Decisions regarding academic matters are made by the Academic Standards Committee of the School of OR&IE. Each student's record is reviewed at the end of each semester upon receipt by the School of semester grades. In cases for which some form of academic action is necessary, students may request the opportunity to appear personally before the committee.

### **Dean's List Certificate**

Dean's List Certificates are issued each semester to students excelling in their studies. The requirements for this honor are:

1. A semester average of 3.5 or higher (not rounded off).
2. 12 letter grade credits (courses graded S/U do not contribute to the 12-credit minimum).
3. No "F"s, "U"s, or incompletes (even in physical education).

Students may earn Dean's List status retroactively if they meet these criteria after making up all incompletes in a semester.

### **Requirements for Graduating with Distinction**

Cum Laude requires a GPA  $\geq 3.50$  either overall or for each of the last four semesters. Magna Cum Laude requires a GPA  $\geq 3.75$  based on all credits taken at Cornell. Summa Cum Laude requires a GPA  $\geq 4.00$  based on all credits taken at Cornell. See "Courses of Study" for detailed information. Dean's List and Distinction are determined by the Engineering Registrar's Office in 158 Olin Hall.

### **Transfers**

Applications to transfer from other majors in the College of Engineering are considered by the Academic Standards Committee on a case-by-case basis. In no event will a student be considered unless:

- 1 the student has completed ENGRD 2700 and MATH 2940 with a grade of "C" or better  
AND
- 2 the student has a combined GPA of 2.2 or higher in mathematics, science and engineering courses, and at least a "C-" in Operations Research and Information Engineering courses (including ENGRD 2110) taken so far.

A student contemplating transfer into ORE should make an appointment with the Associate Director as early as possible. The student will need to complete a Change of Major form available in the Engineering Advising Office in 167 Olin Hall.

Applications to transfer from outside the College of Engineering and Cornell University are handled by the Office of Undergraduate Admissions, Hollister Hall.

### **Course Load**

The minimum course load for a full-time student in the School of Operations Research and Information Engineering is twelve credit hours, **except in the student's final semester**. If a smaller load is carried in any but the final semester, the Registrar will be informed that the student is not full-time. In addition, the Academic Standards Committee may take further academic action before the student's next semester.

### **Exceptions to Curriculum Requirements**

Occasionally a student may perceive a need for an exception to one or more of the curriculum requirements, either a College or School requirement. Such exceptions are considered on a case-by-case basis by the appropriate College or School committee. See the *General Petition Form* shown on page 30.

### **Add/Drop Deadlines**

In line with College policy, a student may freely add and drop courses in the first two weeks of a semester. After the second week, however, the student must petition the Engineering Advising Office to approve any addition and after the seventh week to drop a class. The petition form is available from Heidi Russell in 203 Rhodes Hall. Expectation of a poor or failing grade is NOT sufficient reason for dropping a course.

### **S/U Option**

No more than 15 S/U option credits will count toward a student's degree requirements. A student may take more than one S/U course in any one semester. If a course is offered S/U only, it will not count toward the 15-credit limit. Only courses in the humanities, social sciences, and advisor approved electives may be taken as S/U courses. This decision is irrevocable after the first seven weeks of the term.

### **Approval for Courses Taken at Other Colleges and Universities**

To receive credit for a course taken elsewhere, the student must obtain the approval of the department representative in charge of the course, or the Associate Director and his/her faculty advisor PRIOR to taking the course. The request should be accompanied by written documentation including the name of the college, a course description, the number of credit hours, and the duration of the course (one quarter, one semester, etc.). Only in exceptional circumstances will approval be granted for technical courses; these must be offered by an accredited school of engineering. Forms can be found at <http://www.engineering.cornell.edu/resources/registrar/forms.cfm> or from 203 Rhodes Hall.

It is important to note that transfer credit will NOT be granted for ORIE required major courses except for (1) transfer students who took an equivalent course at another institution prior to enrollment at Cornell, and (2) students formally enrolled in Cornell's Study Abroad program.

### **Credit for Foreign Language Ability**

The School is not involved in giving credit for foreign languages. This is handled through the Office of Admissions and Undergraduate Affairs and the appropriate foreign language department. College policy concerning non-course language credit, i.e., credits obtained with no formal enrollment in a class, is as follows:

"Up to 3 credits may be awarded for competency in a foreign (non-English) language as demonstrated by a score of at least 650 on the CEEB test in the language, or by passing the Cornell Advanced Standing Examination (CASE) in the language. AP credit earned through CASE must be earned prior to a student's first matriculation in the College, or as early as possible in the first semester of the student's residence. In no case will credit be awarded for foreign language competency achieved extracurricularly except under the provisions for AP credit stipulated above."

### **College Policy on Extramural Study, Withdrawal, Leaves of Absence**

**Residence Requirements:** A candidate for an undergraduate degree in engineering shall be required to spend a minimum of four semesters, or the equivalent, in residence (full-time study) at this University, and a minimum of three semesters in residence as a student in a major field of engineering, or in the Independent Major.

**Credit Earned Through Extramural Study:** No more than 11 credits earned through study in the Extramural Division may be used to satisfy the requirements for the bachelor's degree in engineering.

**Study in Absentia:** Candidates for the degree may study away from the campus, with the permission of the appropriate faculty authority. Such students must register for Study in Absentia and pay an appropriate fee. For example, students going on Coop assignments are required to register in Absentia for the term that they are away from campus.

**Leave of Absence:** Students may temporarily suspend study for a period of time by taking a Leave of Absence. A formal petition for Leave of Absence must be filed and written approval must be granted for such a leave to be in effect. Leaves of Absence are normally granted for no more than two years. Credit earned while on Leave of Absence is subject to the limitation placed on extramural credit.

**Withdrawal:** A student who voluntarily withdraws from the degree program severs all connection with the College and University, and may be re-admitted only on formal application for re-admission.

Students who fail either to register within the first three weeks of a semester, or to receive permission for Study in Absentia or Leave of Absence, may be involuntarily withdrawn by action of the faculty.

### **Student Responsibilities**

Each undergraduate enrolled in the School of Operations Research and Information Engineering is responsible for timely selection, registration (including any changes which may be necessary), and completion of appropriate courses in each of several categories needed to fulfill the curriculum requirements of this School and the College of Engineering. Failure to discharge these responsibilities in a timely manner is likely to result in a delay in graduation and/or incorrect entries on the student's transcript. Each student is encouraged to examine his/her CHECKLIST as frequently as necessary. A student may obtain a copy of his/her checklist from the OR&IE Undergraduate Office in 203 Rhodes Hall.

### **ACADEMIC INTEGRITY**

The School of Operations Research and Information Engineering adheres to the policies and procedures of the University on academic integrity, as stated in the *Policy Notebook for Students, Faculty, and Staff* (February, 2000).

The definition of academic integrity, as it appears in the *Policy Notebook* is as follows:

#### **a. General Responsibilities**

1. A student assumes responsibility for the content and integrity of the academic work she/he submits, such as papers, examinations, or reports.
2. A student shall be guilty of violating the Code and subject to proceedings under it if he/she:
  - a. Knowingly represents the work of others as his/her own.
  - b. Uses or obtains unauthorized assistance in any academic work.
  - c. Gives fraudulent assistance to another student.
  - d. Fabricates data in support of laboratory or field work.



b. Specific Guidelines

The following are the specific rules and regulations in regard to the general responsibilities listed under "a":

1. Examinations. During in-class examinations no student may use, give, or receive any assistance or information not given in the examination or by the proctor. No student may take an examination for another student. Between the time a take-home examination is distributed and the time it is submitted for grading by the student, the student may not consult with any persons other than the course professor and teaching assistants regarding the examination. The student is responsible for understanding the conditions under which the examination will be taken.
2. Course Assignments. Students are permitted to consult with others and receive advice and assistance. The copying of another student's work, computation, diagrams, analyses, laboratory reports, or commentaries is prohibited. It is plagiarism and a violation of this Code for anyone to represent another's published work as his own. If materials are taken from published sources, the student must clearly and completely cite the source of such materials. Work submitted by a student and used by a faculty member in the determination of grade in a course may not be submitted by that student in a different course.
3. The crucial underpinning of all specific guidelines regarding academic integrity remains that the student's submitted work, examinations, laboratory reports and term project, must be his/her own work and no one else's.

c. Variations

A faculty member may, at his/her discretion, make additions to or revisions of those guidelines in a particular course. It is his/her responsibility to make clear to his/her students and teaching assistants specific regulations concerning academic integrity that apply to work in his/her course.

In the School of Operations Research and Information Engineering, students are expected to exercise reasonable care to prevent their work from being copied or used by others. Students who knowingly facilitate the use of their work by others will be considered guilty of a violation of academic integrity.

The general procedures to be followed in cases of violation of academic integrity are as follows (details are found in the *Policy Notebook*):

1. The faculty member may summon the student to an interview, called a Primary Hearing, but this is not mandatory; the student is entitled to one week notice of the Primary Hearing. At the primary hearing there must be a third party, appointed by the School, present to witness the proceedings. If the faculty member finds the charge supported, he may impose a penalty of a failing grade in all or part of the course. A finding of guilt is to be reported to the student's college.

In the School of Operations Research and Information Engineering, the penalty for violations of academic integrity is automatic failure of the course involved, unless the faculty member determines that there are mitigating circumstances and chooses to impose a lesser penalty. Courses failed because of such violations may not be dropped.

Violations of academic integrity will be reported to the student's college, which will maintain a record, and may recommend a review by the Dean in cases of repeated violations by a student.

2. The case may be heard by the Academic Integrity Hearing Board of the College of Engineering if:
  - a. The student wishes to appeal the findings of the primary hearing on one of three grounds: lack of due process, excessively harsh penalty, or contested judgment of the faculty member;
  - or
  - b. The faculty member wishes to impose a harsher penalty than failure of the course;
  - or
  - c. The faculty member wishes to omit the primary hearing;
  - or
  - d. The Dean summons the student because of repeated violations.

The Hearing Board may clear the student, affirm the penalty imposed by the faculty member, or impose a harsher penalty, including recording the violation on the student's transcript, suspension, or expulsion.

## **SPECIAL PROGRAMS**

### **Engineering Co-Op Program**

The Co-Op program is an excellent way to obtain practical experience, and therefore the School encourages participation in it. Each Co-Op student is visited by a faculty member while on work assignment. In addition, Co-Op students are invited to keep in contact with the School while on work assignment by calling or writing with any problems or questions. All sophomores and juniors should note that the ORIE summer courses which are offered through the Co-Op program (ORIE 3150, 3300, 3500, etc.) are also open to non Co-Op students. Visit the Engineering Co-Op office (Carpenter Hall) for more information.

### **Cornell University's Study Abroad Program**

Opportunities are available for ORE undergraduates to spend a semester studying abroad. Such opportunities present many advantages, cultural as well as curricular, and are encouraged by ORE. In recent years, for example, ORE students have taken advantage of full-semester programs at the University of New South Wales (Australia), the University of Sydney (Australia), the London School of Economics, University College London, City University London, Hong Kong University of Science & Technology, and CEA Prague (Czech Republic). It is important to note that at each of these universities the students took courses used to fulfill certain (technical) ORE degree requirements; thus the study abroad experience was completed within the students' normal program of study.

Students interested in study abroad opportunities should visit Engineering Advising in 167 Olin Hall for more detail information and application materials.

### **Master of Engineering (ORIE)**

As a two- or three-semester professional degree program, the ORIE Master of Engineering (MEng) has become highly valued in the marketplace and continues to be an attractive option for well prepared undergraduates in Operations Research, Industrial Engineering, Mathematics, Finance, and many other quantitative disciplines.

The main objectives of the MEng program at Cornell are to advance the breadth and depth of our students' technical knowledge and to provide students with opportunities to synthesize and apply this knowledge in a real-world environment. In ORIE, the technical tools of primary importance are mathematical modeling and the application of quantitative techniques instilled within the fields of optimization, probability, stochastic processes, statistics, and simulation. The areas of application for these tools are virtually limitless, but ORIE students generally apply their knowledge to the design, operation, and improvement of business systems.

The capstone component of the ORIE MEng program is the team-based engineering design project, completed with the guidance of a Cornell faculty advisor. The MEng project is fundamentally and purposefully different from traditional coursework and/or the completion of an individual Masters' thesis. The project is intended to prepare students for the professional arena by engaging them in client-sponsored project work with real data, deadlines, and deliverables. Students are expected to play major roles in all aspects of their projects, including formulating and analyzing the problem, managing the client relationship, monitoring the project timeline and milestones, and delivering the final results.

Early program planning is very important for students contemplating the MEng program. For further information please consult the School's Graduate Professional Program Representative (Ms. Kathy King, [kmk23@cornell.edu](mailto:kmk23@cornell.edu)) or the MEng Program Director (Dr. Kathryn Caggiano, [kec4@cornell.edu](mailto:kec4@cornell.edu)). The application deadline for fall admission to the MEng program is January 15. Apply online at <http://www.gradschool.cornell.edu/index.php?p=102>

### **M.S. and Ph.D. Programs**

In the Ph.D. and M.S. programs the problem areas and techniques of operations research are approached from a highly analytical viewpoint. Theories and techniques from mathematical programming, combinatorics, the theory of games, statistics, stochastic processes (queuing and inventory), scheduling, and simulation are developed and used extensively. Consideration is given to the construction of appropriate mathematical

models to represent various real-life operational systems and to the development of techniques for analyzing the performance of these models. Each student pursues a course of study and research emphasizing the use of the mathematical, probabilistic, statistical, and computational sciences. The ultimate goal may range from making a fundamental contribution to the techniques of operations research to applying such techniques to problems in diverse fields. Those students contemplating M.S./Ph.D. study in operations research, either at Cornell, or elsewhere, should use their electives to obtain a strong mathematical background. Therefore, the optimization and applied probability and statistics sequences are recommended, as well as further work in mathematics (Math 4110, 4120, 4310, and 4320) and computer science.

Well-qualified applicants to the M.S./Ph.D. program may receive financial aid in the form of fellowships and teaching and research assistantships. Further information may be obtained from the Associate Director for Graduate Programs.

### **Six-Year Joint Master of Engineering/MBA Program**

The joint Master of Engineering/MBA program allows undergraduates in the College of Engineering to receive a Bachelor's degree and two professional Master's degrees in six years: the M.Eng. (ORIE) degree after the fifth year, and the MBA degree after the sixth year. This program is attractive for several reasons. First, the solid engineering background combined with a business background makes graduates of this program some of the most highly recruited students in the Johnson Graduate School of Management. Second, each year, eight students in this program are chosen as Knight Scholars and receive an award to support each of their two years of graduate study. These awards are named for Mr. Lester B. Knight (ME '29), who has generously provided funding for them. Third, since the MBA is normally a two-year program by itself, the combined program shortens the time needed to complete both degrees by one year.

Planning for this program takes place during the first weeks of the Spring term of the junior year and students must submit a formal application to the Johnson School.

### **Five-Year Program**

This program allows a student to obtain a baccalaureate degree after four years and a professional graduate management degree (MBA, MPA, or MPS) after a fifth year of study with the Johnson Graduate School of Management.

Careful planning is required for a successful integration of the work toward the two degrees. Students accepted for the 5-year program will need to have fulfilled almost all of their undergraduate degree requirements by the end of the junior year. In this way it will be possible to complete most of the first-year core requirements of the Masters degree during the last year of undergraduate studies.

General preparatory courses such as computer science, probability and statistics, calculus, and accounting are taken as part of your required curriculum. Beyond these general preparatory areas, the student should pursue as broad an educational background of elective courses at the undergraduate level as his or her curriculum will allow. The Economics 3010, 3020 (or 1110, 1120, and 3130) sequence should be included in this group. Courses in the humanities and social sciences also enhance the student's preparation for graduate management education.

A small number of Cornell undergraduates, from all colleges in the University, are accepted for the 5-year program each year. The competition for these places is, therefore, extremely keen. Although there are no minimums of grades or test scores, those Cornell students accepted for these programs generally represent a high standard of overall academic achievement. The Admissions Committee considers undergraduate academic performance, scores on the GMAT, work experience, extracurricular activities, and letters of evaluation in reaching admissions decisions. A formal application may be obtained through the Johnson School.

It should be noted that rejection for admission to the 5-year program does not preclude admission as a regular candidate the following year. If a student is rejected and wishes to reapply for regular admission the following year, all that need be done is an update of the same application.

The Graduate Management Admission Test (GMAT) must be taken by January of the student's junior year in order to be considered for admission for the following Fall semester.

As part of the admissions procedures, applicants should request that an official Cornell transcript be sent directly from the Registrar's Office in Day Hall following completion of their first semester of the junior year.

Interviews are required for all 5-year program applicants. Candidates should make an appointment for an interview after their application has been submitted. Interview appointments should be arranged at least two weeks in advance, and may be scheduled by calling the JGSM Admissions Office at 255-4526.

Admissions decisions are usually made by late May, and these decisions are communicated by letter prior to the end of the Spring semester.

During the senior year, students in the 5-year program officially register with their undergraduate college and pay the applicable undergraduate tuition. During the fifth year, these students register with JGSM and pay tuition at the same rate as first year students in the business school. A very limited amount of financial aid is available for students during their fifth year of study.

## **MISCELLANEOUS**

### **Career Services Office**

The Career Services Office (Carpenter Hall) has an extensive recruiting program, and 300-400 interviewing companies come to campus each year. Seniors should visit this office during the first week of classes. Seniors will need to make recruiting preparations early since interview sign-ups usually begin during the second or third week of the semester. Visit this office often and take advantage of the extensive opportunities it offers. The University Placement Office has a series of special lectures on how to approach the job market, preparation of resumes, how to take interviews, etc. Announcements of these lectures and meetings will be posted in Carpenter Hall. The Career Services Office publishes a very informative recruiting handbook that explains the Engineering School Recruiting Process in detail.

### **Cornell Student Chapter of the Institute for Operations Research and the Management Sciences (INFORMS)**

The Student Chapter of INFORMS serves the purpose of introducing students to the professional aspects of the field, career opportunities, and a variety of social activities. There may be guest speakers from industry, plant tours, seminars, intramural teams, a banquet with the parent chapter each spring, a senior banquet and lunches with ORIE faculty. Members benefit by the opportunity to meet other students and professional engineers and to learn about the latest developments and opportunities in OR&IE.

As a service to the students and the School, INFORMS presents awards for Outstanding Professor and Teaching Assistant, constructs a composite of each graduating class, and creates displays for the showcase. The peer advisory program gives students the opportunity to consult with seniors and graduate students concerning course selections and career planning.

### **The Society of Women Engineers**

The Society of Women Engineers is a professional, non-profit, educational service organization of graduate engineers and men and women with equivalent engineering experience. The objective of the Society is to encourage, assist, and inform young women, parents and counselors of the opportunities open to women in engineering. Hosting the Northeast Regional Conference and conducting a conference for high school students are a few of the major activities undertaken by the very active Cornell Chapter of SWE. The SWE mailing address is 162 Olin Hall.

## **Seminars**

In addition to the speakers sponsored by INFORMS, two regular seminar programs are organized by the School. There is a weekly seminar held on Tuesdays from 4:15-5:30 on research topics, and a seminar held on Wednesday from 4:30-5:30 on recent applications. Although the seminars are intended for faculty and graduate students, undergraduates are welcome. Notices are posted on the bulletin board near the student mailboxes.

NOTE: ORIE 9000, 9100, 9101 or 9110 MAY NOT be used to fill the ORIE Elective requirement.

## **Awards for Outstanding ORIE Graduating Students**

Several prizes have been established to recognize outstanding academic accomplishment in the Operations Research Engineering program, with certain awards designated specifically for students who intend to pursue the Master of Engineering degree. These prizes are named in honor of Cornell graduates who have made significant contributions in the field of Operations Research and Information Engineering.

Lynn E. Bussey dedicated his career to the teaching of engineering economics. His well-known text, "The Economic Analysis of Industrial Projects", is valued as a particularly thorough treatment of this topic at the graduate level. The Lynn Bussey Prize is awarded annually at commencement to an outstanding student in ORE who is continuing in the ORIE Master of Engineering Program.

Allan H. Mogensen was one of the pioneers in the field of industrial engineering. He developed the concept of work simplification in the 1920's and led the movement for quality work and employee involvement from 1929 until his retirement in 1985. The Allan H. Mogensen award is also designated for an outstanding student in ORE who is continuing in the ORIE Master of Engineering Program.

The Byron W. Saunders Award is named in honor of a former faculty member of the School of OR&IE who also served as Dean of the University Faculty. Professor Saunders devoted his energy for many years to the encouragement of excellence in academic performance by ORE undergraduates. The Saunders prize is awarded each spring to the senior(s) who have achieved the best academic record in the School of OR&IE.

In 2008, Samuel M. Dell III ('65, MEng '66), a leader and manager at Exxon Mobil for 35 years, established the Geraldine and Sam Dell Master of Engineering Fellowship. This award recognizes exceptional students who were undergraduates at Cornell University and are pursuing a MEng in ORIE. The recipient(s) must demonstrate strong ethical grounding, leadership, teamwork, and have a fundamental understanding of the application of theory to practical business problems.

## **Suggestions Requested**

This handbook was written to provide information to students who are currently enrolled in, or who are planning to enroll in the School of Operations Research and Information Engineering. Your suggestions would be appreciated. Please leave your comments in the School Office.

## **Appendix I: Courses Offered in ORIE**

### **ENGRI 1101 Engineering Applications of Operations Research**

Fall, Spring. 3 credits. Enrollment not open to ORE upper-class majors.

An introduction to the problems and methods of Operations Research and Industrial Engineering focusing on problem areas (including inventory, network design, and resource allocation), the situations in which these problems arise, and several standard solution techniques. In the computational laboratory, students encounter problem simulations and use some standard commercial software packages.

### **ENGRD 2700 Basic Engineering Probability and Statistics**

Fall, Spring, Summer. 3 credits. Pre- or corequisite: MATH 2940.

This course gives students a working knowledge of basic probability and statistics and their application to engineering. Computer analysis of data and simulation are included. Topics include random variables, probability distributions, expectation, estimation, testing, experimental design, quality control, and regression.

### **ORIE 1380 Data Science for All**

Spring. 4 credits. Enrollment not open to ORE upper-class majors.

This course provides an introduction to data science. Given data from economics, medicine, biology, or physics, collected from internet denizens, survey respondents, or wireless sensors, how can one understand the phenomenon generating the data, make predictions, and improve decisions? We focus on building skills in inferential thinking and computational thinking, guided by the practical questions we seek to answer. The course teaches critical concepts and skills in computer programming and statistical inference, in conjunction with hands-on analysis of real-world datasets including economic data, document collections, geographical data, and social networks. We will also consider social issues in data analysis such as privacy and design.

### **ORIE 2380 Urban Analytics**

Fall. 3 credits. Enrollment not open to ORE upper-class majors.

Data documenting urban life is being collected at a scale unimaginable just a few years ago. And yet, the use of urban data to improve our quality of life has its roots in stemming the 1854 cholera outbreak in London. Through a series of case studies, this course will explore a number of facets of the use of urban data in understanding, forecasting, and decision-making in our lives today, starting with this example in epidemiology, but continuing with modern transit (including ride- and bike-sharing), emergency services, criminology, and environmental monitoring/planning. The course will emphasize the role of mathematical, statistical and computational models in these settings.

### **ORIE 3120 Practical Tools for Operations Research, Machine Learning and Data Science**

Spring. 4 credits. Prerequisite: ENGRD 2700 (may be taken concurrently).

The practical use of software tools and mathematical methods from operations research, machine learning, statistics and data science. Software tools include structured query language (SQL), geographical information systems (GIS), Excel and Visual Basic programming (VBA), and programming in a scripting language (either R or Python). Operations research methods include inventory management, discrete event simulation, and an introduction to the analysis of queuing systems. Machine learning and statistical methods include multiple linear regression, classification, logistic regression, clustering, time-series forecasting, and the design and analysis of A/B tests. These topics will be presented in the context of business applications from transportation, manufacturing, retail, and e-commerce.

### **ORIE 3150 Financial and Managerial Accounting**

Fall. 4 credits.

Course covers: principles of accounting, financial reports, financial-transactions analysis, financial-statement analysis, budgeting, job-order and process-cost systems, standard costing and variance analysis, and economic analysis of short-term decisions.

**ORIE 3300 Optimization I**

Fall. 4 credits. Prerequisite: grade of C- or better in MATH 2210 or 2940.

Formulation of linear programming problems and solutions by the simplex method. Related topics such as sensitivity analysis, duality, and network programming. Applications include such models as resource allocation and production planning. Introduction to interior-point methods for linear programming.

**ORIE 3310 Optimization II**

Spring. 4 credits. Prerequisite: grade of C- or better in ORIE 3300 or permission of instructor.

A variety of optimization methods stressing extensions of linear programming and its applications but also including topics drawn from integer programming, dynamic programming, and network optimization. Formulation and modeling are stressed as well as numerous applications.

**ORIE 3500 Engineering Probability and Statistics II**

Fall. 4 credits. Prerequisite: grade of C- or better in ENGRD 2700 or equivalent.

This second course in probability and statistics provides a rigorous foundation in theory combined with the methods for modeling, analyzing, and controlling randomness in engineering problems. Probabilistic ideas are used to construct models for engineering problems, and statistical methods are used to test and estimate parameters for these models. Specific topics include: random variables, probability distributions, density functions, expectation and variance, multidimensional random variables, and important distributions including normal, Poisson, exponential, hypothesis testing, confidence intervals, and point estimation using maximum likelihood and the method of moments.

**ORIE 3510 Introductory Engineering Stochastic Processes I**

Spring. 4 credits. Prerequisite: grade of C- or better in ORIE 3500 or equivalent.

Basic concepts and techniques of random processes are used to construct models for a variety of problems of practical interest. Topics include the Poisson process, Markov chains, renewal theory, models for queuing, and reliability.

**ORIE 3800 Information System and Analysis**

4 credits.

Presents a systematic and hierarchical approach to the development of information systems, featuring business case justification, requirements analysis, use case analysis, functional analysis, structural design, object-oriented modeling, database design, verification and validation, and project schedule estimation. Graphical tools of analysis (e.g., the Unified Modeling Language) are emphasized. Examples are drawn from business and industrial processes. An integrative design project resulting in detailed information system design specification (but not necessarily implementation) is required.

**ORIE 4120 Inventory, Operations, and Supply Chain Management: Models & Optimization**

Fall. 2 credits.

This course will provide a rigorous coverage of the (stochastic and deterministic) models commonly used in the study of inventory, operations, and supply chain management. This includes the multi-period newsvendor model and its many variants, as well as more sophisticated models which arise in supply chain management, logistics, and the study of operations more broadly. We will study tools for analyzing and optimizing such systems, as well as operational insights which can be extracted from such models. The course will in general have a fairly mathematical orientation, focusing on using tools from stochastic modeling, optimization, and dynamic programming/algorithms to formulate and analyze these models.

**ORIE 4130 Service System Modeling and Design**

3 credits. Prerequisites: ORIE 3310 or 5311; ability to program simple algorithms in some appropriate environment (e.g., VisualBasic or MATLAB).

Today's economy is dominated by service industries. These systems differ from manufacturing industries in many ways, but primarily in the level of interaction with the customer. Examples of service systems include contact centers (aka call centers), airlines, and hospitals. This course covers various techniques that are useful in the analysis and design of such systems. The class is structured around a number of cases that drive the need for the theory. The emphasis is on modeling and solving the models. Both operational and strategic decisions are covered through appropriate examples.

**ORIE 4150 Economic Analysis of Engineering Systems**

4 credits. Prerequisites: ORIE 3300 and ORIE 3150.

Course topics include: financial planning, including cash-flow analysis and inventory flow models; engineering economic analysis, including discounted cash flows and taxation effects; application of optimization techniques, as in equipment replacement or capacity expansion models, and issues in designing manufacturing systems. Includes a student group project.

**ORIE 4152 Entrepreneurship for Engineers (also ENGRG 4610)**

3 credits. Enrollment open to upper class engineers; others with permission of instructor.

This course develops skills necessary to identify, evaluate, and begin new business ventures. Topics include intellectual property, competition, strategy, business plans, technology forecasting, finance and accounting, and sources of capital. A rigorous, quantitative approach is stressed throughout, and students create financial documents and plans, analyze human resource models, and work with sophisticated valuation methods, complicated equity structures, and legal and business documents. As such, this course represents the "red meat" of entrepreneurship, and the soft skills are left for other courses. Coursework consists of discussions, assignments, and the preparation and presentation of a complete business plan.

**ORIE 4154 Revenue Optimization and Marketplace Design**

3 credits, Prerequisites: ORIE 3300 and 3500, or permission of instructor

Application of modeling and optimization techniques in designing a company's interface with the market. We will cover a variety of topics (product pricing and capacity control; designing product assortments and customer segmentation; the use of customer data in modeling and optimization; the design of online platforms and markets), with examples from transportation, retail, hospitality and the sharing economy.

**ORIE 4300 Optimization Modeling**

3 credits. Prerequisites: a grade of at least B- in ORIE 3310/5310.

Emphasis is on modeling complicated decision problems as linear programs, integer programs, or highly-structured nonlinear programs. Besides modeling, students are required to assimilate articles from the professional literature and to master relevant software.

**ORIE 4330 Discrete Models**

4 credits. Prerequisites: ORIE 3300 and CS 2110, or permission of instructor.

Course covers basic concepts of graphs, networks, and discrete optimization. Fundamental models and applications, and algorithmic techniques for their analysis. Specific optimization models studied include flows in networks, the traveling salesman problem, and network design.

**ORIE 4350 Introduction to Game Theory**

4 credits. Prerequisites: ORIE 3300

A broad survey of the mathematical theory of games, including such topics as: two-person matrix and bimatrix games; cooperative and noncooperative n-person games; and games in extensive, normal, and characteristic function form. Economic market games. Applications to weighted voting and cost allocation.

**ORIE 4520 Introductory Engineering Stochastic Processes II**

4 credits. Prerequisite: ORIE 3510 or equivalent.

Course topics include: stationary processes, martingales, random walks, and gambler's ruin problems, processes with stationary independent increments, Brownian motion and other cases, branching processes, renewal and Markov-renewal processes, reliability theory, Markov decision processes, optimal stopping, statistical inference from stochastic models, and stochastic comparison methods for probability models. Applications to population growth, spread of epidemics, and other models.

**ORIE 4580 Simulation Modeling and Analysis**

4 credits. Prerequisite: ORIE 3500 (may be taken concurrently) and CS/ENGRD 2110.

Introduction to Monte Carlo and discrete-event simulation. Emphasis on tools and techniques needed in practice. Random variate generation, input and output analysis, modeling using a discrete-event simulation package.

**ORIE 4600 Introduction to Financial Engineering**

3 credits. Prerequisites: ORIE 3500 and 3510.



This is an introduction to the most important notions and ideas in modern financial engineering, such as arbitrage, pricing, derivatives, options, interest rate models, risk measures, equivalent martingale measures, complete and incomplete markets, etc. Most of the time the course deals with discrete time models. This course can serve as a preparation for a course on continuous time financial models such as OR&IE 568.

**ORIE 4630 Operations Research Tools for Financial Engineering.**

3 credits. Prerequisites: engineering math through MATH 2940 and ORIE 2700 and 3500.

This course is an introduction to the applications of OR techniques, e.g., probability, statistics, and optimization, to finance and financial engineering. No previous knowledge of finance is required. The course first reviews probability and statistics and then surveys assets returns, ARIMA time series models, portfolio selection, regression, CAPM, option pricing, GARCH models, fixed-income securities, resampling techniques, and behavioral finance. The use of MATLAB, MINITAB, and SAS for computation is also covered.

**ORIE 4740 Statistical Data Mining**

4 credits. Prerequisites: ORIE 3500 and MATH 2940 or equivalent; programming experience. Exposure to multiple linear regression and logistic regression strongly recommended.

This course examines the statistical aspects of data mining, the effective analysis of large data sets. The first half of the course covers the process of building and interpreting statistical models in a variety of settings including multiple regression and logistic regression. The second half connects these ideas to techniques being developed to handle the large data sets that are now routinely encountered in scientific and business applications. Assignments are done using one or more statistical computing packages.

**ORIE 4741 Learning with Big Messy Data**

4 Credits. Prerequisite: linear algebra and matrix notation, a modern scripting language (Python, Matlab, Julia, R), and basic complexity on  $O(n)$  notations.

Modern data sets, whether collected by scientists, engineers, medical researchers, government, financial firms, social networks, or software companies, are often big, messy, and extremely useful. This course addresses scalable robust methods for learning from big messy data. We'll cover techniques for learning with data that is messy — consisting of real numbers, integers, booleans, categoricals, ordinals, graphs, text, sets, and more, with missing entries and with outliers — and that is big — which means we can only use algorithms whose complexity scales linearly in the size of the data. We will cover techniques for cleaning data, supervised and unsupervised learning, finding similar items, model validation, and feature engineering. The course will culminate in a final project in which students extract useful information from a big messy data set.

**ORIE 4742 Information Theory, Probabilistic Modeling, & Deep Learning with Scientific & Financial Applications**

3 credits. Prerequisite: ORIE 3500 and MATH 2940. Programming experience. Exposure to statistical machine learning at the level of ORIE 4740 or ORIE 4741.

This course is about building and understanding machine learning models for scientific and financial applications. It will cover foundational aspects of information theory and probabilistic inference as they relate to model construction and deep learning. Topics include hamming codes, repetition codes, entropy, mutual information, Shannon information, channel capacity, likelihood functions, Bayesian inference, graphical models, and deep neural networks. The section on deep neural networks will consider fully connected, convolutional, recurrent, and LSTM networks, generative adversarial training, and variational autoencoders.

**ORIE 4820 Spreadsheet-Based Modeling and Data Analysis**

3 credits. Prerequisites: ORIE 3300, ENGRD 2700, or equivalent.

Students develop and implement practical spreadsheet models to analyze data and evaluate decision problems in a hands-on learning environment. Microsoft Excel is heavily used. A wide variety of application areas are covered that incorporate concepts from probability, statistics, and constrained optimization.

**ORIE 5100 Design of Manufacturing Systems**

4 credits. Senior OR&E students only. Others by permission of instructor only.

This is a project course in which students, working in teams, design a manufacturing logistics system and conduct capacity, material flow, and cost analysis of their design. Meetings between project teams and faculty advisers are substituted for some lectures.

Analytical methods for controlling inventories, planning production, and evaluating system performance are presented in lectures.

**ORIE 5122 Inventory Management**

3 credits. Prerequisite: ORIE 3310, 3510, or permission of instructor.

The first portion of this course is devoted to the analysis of several deterministic and probabilistic models for the control of single and multiple items at one of many locations. The second portion of this course is presented in an experiential learning format. The focus is on analyzing and designing an integrated production and distribution system for a global company. Applications are stressed throughout.

**ORIE 5126 Principles of Supply Chain Management**

4 credits. Prerequisites ORIE 3310, 3510, or MBA courses in operations management.

Supply chain management focuses on the flow of products, information, and money through organizations that constitute the supply chain. The course provides an overview of the key principles on which an effective supply chain should be constructed. These principles are presented and illustrated through a collection of cases. These cases are taught using an experiential learning model. Additionally, applications of analytic and simulation tools to the design and operation of supply chains are given.

**ORIE 5140 Model Based Systems Engineering**

4 credits. Prerequisites: senior or graduate standing in an engineering field; concurrent or recent (past two years) enrollment in a group-based project with a strong system design component that is approved by a course instructor.

Fundamental ideas of systems engineering, and their application to design and development of various types of engineered systems. Defining system requirements, creating effective project teams, mathematical tools for system analysis and control, testing and evaluation, economic considerations, and the system life cycle.

**ORIE 5142 Systems Analysis Architecture, Behavior, and Optimization**

3 credits. Prerequisite: ORIE 5140.

An advanced course in the application of the systems engineering process to the design and operation of complex systems. It focuses on the descriptive and analytical tools of systems engineering including optimization, discrete event simulation, dynamic systems, statistics for design and control, and decision analysis. Case studies are presented in the application of these techniques to space transportation, power, manufacturing, transportation, nuclear power licensing, and military systems.

**ORIE 5370 Optimization Modeling in Finance**

3 credits. Prerequisites: Familiarity with optimization modeling and basic knowledge of statistics, probability and finance.

Explores optimization in the context of finance, including methodologies beyond linear programming, such as second-order cone programming and semidefinite programming. Topics include Markowitz portfolio theory and modeling, factor models for portfolio selection and risk control; the Black-Litterman model (and related Bayesian topics); utility functions; coherent risk measures; stochastic programming; and optimal execution of portfolio transactions. Emphasis is on concepts that are directly implementable. Homework and project require considerable coding in MATLAB.

**ORIE 5550 Applied Time-Series Analysis**

4 credits. Prerequisites: ORIE 3510, or permission of instructor.

The first part of this course treats regression methods to model seasonal and nonseasonal data. After that, Box-Jenkins models, which are versatile, widely used, and applicable to nonstationary and seasonal time series, are covered in detail. The various stages of model identification, estimation, diagnostic checking, and forecasting are treated. Analysis of real data is carried out. Assignments require computer work with a time-series package.

**ORIE 5582 Monte Carlo Methods in Financial Engineering**

2 credits. Weeks 8-14. Prerequisite: ORIE 4580

An overview of Monte Carlo methods as they apply in financial engineering. Generating sample paths. Variance reduction (including quasi random number), discretization, and sensitivities. Application to derivative pricing and risk management.

**ORIE 5600 Financial Engineering with Stochastic Calculus I**

4 credits. Prerequisite: knowledge of probability at the level of ORIE 3500.

This course is an introduction to continuous-time models of financial engineering and the mathematical tools required to use them, starting with the Black-Scholes model. Driven by the problem of derivative security pricing and hedging in this model, the course develops a practical knowledge of stochastic calculus from an elementary standpoint, covering topics including Brownian motion, martingales, the Ito formula, the Feynman-Kac formula, and Girsanov transformations.

**ORIE 5610 Financial Engineering with Stochastic Calculus II**

4 credits. Prerequisite: ORIE 5600.

Building on the foundation established in ORIE 5600, this course presents no-arbitrage theories of complete markets, including models for equities, foreign exchange, and fixed income securities, in relation to the main problems of financial engineering: pricing and hedging of derivative securities, portfolio optimization, and risk management. Other topics include model calibration and incomplete markets.

**ORIE 5620 Credit Risk: Modeling, Valuation and Management**

3 credits. Prerequisite: ORIE 5600.

Credit risk refers to losses due to changes in the credit quality of a counter party in a financial contract. This course is an introduction to the modeling and valuation of credit risks. Emphasis is on credit derivative instruments used for hedging credit risks, including credit swaps, spread options, and collateralized debt obligations.

**ORIE 5640 Statistics for Financial Engineering**

4 credits. Pre- or corequisite ORIE 3500 and at least one of OIRE 4600, 4630 or 5600.

Time series, GARCH, and stochastic volatility models. Calibration of financial engineering models. Estimation of diffusion models. Data mining in financial engineering. Estimation of risk measures. Bayesian statistics. This course is intended for M.Eng. student in financial engineering and assumes some familiarity with finance and financial engineering. Students not in the M.Eng. program are welcome if they have a suitable background. Students with no background in finance should consider taking ORIE 4600.

**ORIE 5650 Quantitative Methods of Financial Risk Management**

3 credits. Prerequisites: ORIE 3500

Market Risk. We start with a historical perspective of market risk measurement including the Markowitz, CAPM and APT models. We will then give a closer description of the value-at-risk approach and give an overview of VaR variants and extensions such as delta-VaR, CVaR etc. This section will require a survey of extreme value methods for determining VaR. We will also survey rapidly other methods for evaluating risk and consider multivariate methods for evaluating portfolios requiring copula tools which have become popular. Time permitting, we will survey topics in credit risk: methods for determining default probabilities and company ratings based on financial ratios (logit, probit and discriminant analysis, decision trees etc.), and introduce the main approaches to measuring credit risk which can be roughly divided into structural models and reduced-form models.

**School of Operations Research & Information Engineering  
Approved Elective Form**

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**Name** \_\_\_\_\_  
**Expected Degree Date**

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**Email Address** \_\_\_\_\_  
**CU ID Number** \_\_\_\_\_  
**Advisor's Name**

**Course to be applied towards the Approved Elective Requirement (6 credits total):**

Course #	Course Title	Term Taken
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**Advisor's Signature** \_\_\_\_\_  
**Date**

(Please submit form to ORIE Undergraduate Office in 203 Rhodes.)

**School of Operations Research & Information Engineering  
General Petition Form**

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**Last Name**

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**First Name**

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**Today's Date**

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**Expected graduation date**

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**Advisor's Name**

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**Email Address**

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**I request permission to:**

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**Signature**

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**Date**

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**Advisor Statement:**

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**Signature**

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**Date**

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**Departmental Approval:**

\_\_\_\_\_ **Request Approved**

\_\_\_\_\_ **Request Denied**

**Comments:**

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**Associate Director, ORE**

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**Date**