DEPARTMENT OF STATISTICAL SCIENCES AND OPERATIONS RESEARCH

D’Arcy P. Mays III, Ph.D.
Associate professor and chair

ssor.vcu.edu (https://ssor.vcu.edu/)

The Department of Statistical Sciences and Operations Research offers programs leading to a Bachelor of Science in Mathematical Sciences, a Master of Science in Mathematical Sciences with a concentration in either operations research or statistics and a Doctor of Philosophy in Systems Modeling and Analysis. The curriculum of the programs is run jointly with the Department of Mathematics and Applied Mathematics (http://bulletin.vcu.edu/undergraduate/college-humanities-sciences/departmentofmathematicsandappliedmathematics/).

The department also offers a post-baccalaureate undergraduate certificate in statistics.

- Mathematical Sciences, Master of Science (M.S.) with a concentration in operations research (http://bulletin.vcu.edu/graduate/college-humanities-sciences/statistical-sciences-operations-research/mathematical-sciences-ms-concentration-operations-research/)
- Mathematical Sciences, Master of Science (M.S.) with a concentration in statistics
- Systems Modeling and Analysis, Doctor of Philosophy (Ph.D.) (http://bulletin.vcu.edu/graduate/college-humanities-sciences/mathematics-applied-mathematics/systems-modeling-analysis-phd/)
- Applied Statistics, Certificate in (Graduate certificate) (http://bulletin.vcu.edu/graduate/college-humanities-sciences/statistical-sciences-operations-research/applied-statistics-certificate/)
- Statistical sciences (STAT) (p. 1)
- Operations research (OPER) (p. 4)
- Statistical sciences and operations research (SSOR) (p. 6)
- Systems modeling and analysis (SYMS) (p. 6)

Statistical sciences

STAT 508. Introduction to Social Statistics. 3 Hours.
Semester course; 2 lecture and 2 laboratory hours. 3 credits. Introduction to statistical methods applicable in a variety of settings, with emphasis on nonexperimental data. Data description and analysis including chi-square and t-tests, using a statistical computing package. Not applicable toward M.S. in Mathematical Sciences or Computer Science. Crosslisted as: SOCY 508.

STAT 513. Mathematical Statistics I. 3 Hours.
Continuous course; 3 lecture hours. 3 credits. Prerequisite: MATH 307. Probability, random variables and their properties, distributions, moment generating functions, limit theorems, estimators and their properties; Neyman-Pearson and likelihood ratio criteria for testing hypotheses. Crosslisted as: BIOS 513.

STAT 514. Mathematical Statistics II. 3 Hours.
Continuous course; 3 lecture hours. 3 credits. Prerequisite: STAT 513/BIOS 513. Probability, random variables and their properties, distributions, moment generating functions, limit theorems, estimators and their properties; Neyman-Pearson and likelihood ratio criteria for testing hypotheses. Crosslisted as: BIOS 514.

STAT 543. Statistical Methods I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with graduate standing, or those with one course in statistics and permission of instructor. Basic concepts and techniques of statistical methods, including the collection and display of information, data analysis and statistical measures; variation, sampling and sampling distributions; point estimation, confidence intervals and tests of hypotheses for one and two sample problems; principles of one-factor experimental design, one-way analysis of variance and multiple comparisons; correlation and simple linear regression analysis; contingency tables and tests for goodness of fit. Students may receive degree credit for only one of BIOS 543, STAT 441, STAT 541, STAT 543 or STAT 641. Neither STAT 543 nor BIOS 543 is applicable toward the M.S. degree in mathematical sciences or the M.S. degree in computer science.

STAT 544. Statistical Methods II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 305, STAT 314, STAT 441, STAT 541 or STAT 543, or an equivalent. Advanced treatment of the design of experiments and the statistical analysis of experimental data using analysis of variance and multiple-regression. Includes the use of a statistical software package for data analysis. Students may receive degree credit for only one of BIOS 544 or STAT 544.

STAT 546. Linear Models. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 513 and one applied course in statistics, or permission of instructor. A study of the theory underlying the general linear model and general linear hypothesis. Topics include the general linear model for quantitative responses (including multiple regression, analysis of variance and analysis of covariance), binomial regression models for binary data (including logistic regression and probit models) and Poisson regression models for count data (including log-linear models for contingency tables and hazard models for survival data).

STAT 591. Topics in Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated for credit. Prerequisite: Permission of the instructor. Course open to qualified undergraduates. Selected topics in statistics.

STAT 608. Statistics for Social Research. 3 Hours.
Semester course; 2 lecture and 2 laboratory hours. 3 credits. Prerequisite: STAT/SOCY 508 or SOCY 214 or permission of instructor. Statistical methods applied in social research. Topics include analysis of variance, correlation and regression, including stepwise methods, and the analysis of discrete data. Study of a statistical package, emphasizing manipulation of survey data sets. Not applicable toward M.S. in Mathematical Sciences or Computer Science. Crosslisted as: SOCY 608.

STAT 613. Stochastic Processes. 3 Hours.
Continuous courses; 3 lecture hours. 3-3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of instructor. Introduction to the theory and applications of stochastic processes. Random walks, Markov processes, queueing theory, renewal theory, birth-death and diffusion processes. Time series, spectral analysis, filter, autocorrelation.
STAT 614. Stochastic Processes. 3 Hours.
Continuous courses; 3 lecture hours. 3-3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of instructor. Introduction to the theory and applications of stochastic processes. Random walks, Markov processes, queuing theory, renewal theory, birth-death and diffusion processes. Time series, spectral analysis, filter, autocorrelation.

STAT 621. Nonparametric Statistical Methods. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: any two courses of statistics or permission of instructor. Estimation and hypothesis testing when the form of the underlying distribution is unknown. One-, two- and k-sample problems. Tests of randomness, Kolmogorov-Smirnov tests, analysis of contingency tables and coefficients of association. Crosslisted as: BIOS 621.

STAT 623. Discrete Multivariate Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. Methods for the analysis of categorical data, including logistic regression and the general log-linear model. Emphasis on social and biomedical applications of these techniques using SPSS and SAS software.

STAT 625. Applied Multivariate Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of instructor. Multivariate statistics is a study of dependent random variables. This course covers methods for analyzing continuous multivariate data, such as numerical and graphical summary of multivariate observations, principal component analysis, factor analysis, classification and discrimination, canonical correlation analysis, and cluster analysis. Students will learn the motivation behind these methods, how to implement them in statistical software packages and how to interpret the results.

STAT 626. Complex Sampling Designs and Variance Estimation. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 544 and 514. The analysis of data from surveys that use multistage samples, and connections to the analysis of observational studies and experiments with missing data. Computer intensive methodologies such as the jackknife and bootstrap will be introduced and applied to the problem of variance estimation in these diverse settings.

STAT 636. Machine Learning Algorithms. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with graduate status in mathematical sciences, systems modeling and analysis, decision sciences and business analytics, or computer science, or by permission of the instructor. Includes an in-depth analysis of machine learning algorithms for data mining, equipping students with skills necessary for the design of new algorithms. Analyses will include framing algorithms as optimization problems and a probabilistic analysis of algorithms. Students will be exposed to current areas of research in the construction of data mining algorithms. Crosslisted as: OPER 636.

STAT 641. Applied Data Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students who have completed a multivariate calculus course. Experience with mathematics or statistics software is strongly recommended. Introduction to applied data analysis intended primarily for graduate students in mathematical sciences and engineering. Topics include the fundamental ideas of descriptive statistics, elementary probability theory, statistical inference including tests of hypotheses and confidence intervals, ANOVA, principles of experimental design, correlation and linear regression analysis, categorical data analysis, and quality control. Focus is on the practical side of implementing these techniques using statistical software packages. Students may receive degree credit for only one of BIOS 543, STAT 441, STAT 541, STAT 543 or STAT 641.

STAT 642. Design and Analysis of Experiments I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of instructor. An introduction to the design and analysis of experiments. Topics include the design and analysis of completely randomized designs, one variable block designs, the family of Latin square designs and split-plot designs. Introductions are also given to multiple comparison procedures and contrasts, analysis of covariance and factorial experiments. Applications involve the use of a statistical software package.

STAT 643. Applied Linear Regression. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 200-201, STAT 212 and MATH 310 or equivalents. An introduction to the concepts and methods of linear regression analysis. Topics include simple linear regression, multiple linear regression, the impact of model misspecification, model selection criteria, residual analysis, influence diagnostics, diagnostic plots, multicollinearity, transformations and response surface methodology. Applications involve the use of a statistical software package.

STAT 645. Bayesian Decision Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 514 or equivalent. Presents statistical decision theory and Bayesian analysis, with discussions of loss functions, risk, utility, prior information; conjugate families; posterior distributions, estimation, hypothesis testing; empirical and hierarchical Bayes analysis; and robustness.

STAT 648. Systems Reliability Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. An introduction to engineering reliability and risk analysis, specifically failure data analysis, maintenance problems, system reliability and probabilistic risk assessment. Applications in computer science and engineering will include stochastic characterization of wear in hardware systems and the development of failure models for software systems. Decision problems such as the optimal maintenance of repairable systems and optimal testing policies for hardware and software systems will be examined. The analysis of risk through fault trees, event trees and accident precursor analysis also will be discussed. Crosslisted as: OPER 648.
STAT 649. Statistical Quality Control. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. Demonstrates how statistics and data analysis can be applied effectively to process control and management. Topics include the definition of quality, its measurement through statistical techniques, variable and attribute control charts, CUSUM charts, multivariate control charts, process capability analysis, design of experiments, and classical and Bayesian acceptance sampling. Statistical software will be used to apply the techniques to real-life case studies from manufacturing and service industries. Crosslisted as: OPER 649.

STAT 650. Design and Analysis of Response Surface Experiments. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. Philosophy, terminology and nomenclature for response surface methodology, analysis in the vicinity of the stationary point, canonical analysis, description of the response surface, rotatability, uniform information designs, central composite designs and design optimality. Crosslisted as: BIOS 650.

STAT 675. Time Series Analysis I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of instructor. Analysis of data when observations are not mutually independent, stationary and nonstationary time series, ARIMA modeling, trend elimination, seasonal models, intervention analysis, transfer function analysis, prediction and applications in economics and engineering.

STAT 691. Special Topics in Statistics. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be repeated for credit. Prerequisite: Permission of instructor. A detailed study of selected topics in statistics.

STAT 696. Applied Project. 1-3 Hours.
Semester course; 1-3 lecture hours (to be arranged). 1-3 credits. Up to three credits will be applied to the M.S. in Mathematical Sciences (operations research or statistics concentration) per section. Can be repeated for credit. Prerequisite: SSOR 690 or permission of the faculty adviser. Designed to allow students to apply concepts and theories learned in other courses to a practical situation. Includes the selection, written description, completion and written report of the project and a presentation of the findings. Students may not receive credit for both OPER/STAT 696 and OPER/STAT 698. Graded as Satisfactory/Unsatisfactory. Crosslisted as: OPER 696.

STAT 697. Directed Research. 1-3 Hours.
Semester course; variable hours. 1-3 credits per semester. May be repeated for credit. Prerequisite: Graduate standing. Supervised individual research and study in an area not covered in the present curriculum or in one that significantly extends present coverage. Research culminates with an oral presentation and submission of a written version of this presentation to the supervising faculty member.

STAT 698. Thesis. 1-3 Hours.
Hours to be arranged. 1-3 credits. A total of 3 or 6 credits may be applied to the M.S. in Mathematical Sciences/Statistics. (A total of 3 credits for an expository thesis or a total of 6 credits for a research thesis.) May be repeated for credit. Prerequisite: Graduate standing. Independent research culminating in the writing of the required thesis as described in this bulletin. Grade of "S," "U" or "F" may be assigned in this course.

STAT 725. Advanced Multivariate Statistical Methods. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 625 and STAT 643. This course emphasizes statistical analysis, methodology and theory in modern statistical learning. A variety of multivariate statistical methods, algorithms and software tools will be introduced, with emphasis on conceptual, theoretical and computational aspects. Topics include regularized regression (linear/nonlinear), classification, clustering, sufficient dimension reduction and high dimensional data analysis. Applications involve the use of a statistical software package.

STAT 736. Mathematics of Knowledge and Search Engines. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 541 or equivalent. Investigates the mathematics, methods and algorithms for searching for and extracting structures of interest (knowledge) from large and possibly high-dimensional datasets. The motivation is the rapid and phenomenal growth of the search engine (as demonstrated by Google) as a major tool for search on the Internet, which has impacted commerce, education and the study of social, financial and scientific datasets. The development of the mathematical and statistical learning algorithms behind these search engines has led to advances in how large, high-dimensional datasets can be effectively analyzed for the extraction of knowledge. Crosslisted as: OPER 736.

STAT 742. Design and Analysis of Experiments II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 642. Advanced study of the design and analysis of experiments. Topics include the design and analysis of incomplete block designs, factorial designs, fractional factorial designs, asymmetric factorial designs, blocking in fractional factorial designs, nested designs and response surface designs. Applications involve the use of a statistical software package.

STAT 744. Regression II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 643 or equivalent. Theoretical development and advanced applications of the general linear regression model and nonlinear regression models. Topics include an overview of multiple linear regression, generalized least squares and weighted regression, procedures for diagnosing and combating multicollinearity, advanced model selection criteria, influence diagnostics including multiple observation diagnostics and singular value decomposition, nonlinear regression, Poisson regression, logistic regression, generalized linear models and the exponential family, variance modeling and nonparametric regression. Applications involve the use of a statistical software package.

STAT 745. Advanced Bayesian Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 546 and STAT 645 or permission of instructor. Introduces modern aspects of Bayesian methodology. Numerical and sampling techniques such as the Gibbs sampler, importance sampling resampling, Monte Carlo integration, Metropolis-Hastings sampling and adaptive sampling methods. Inferential methods including model selection, highest probability models, Bayesian model averaging, Markov chain Monte Carlo model composition. A large portion of the course will survey the current literature in the areas listed above as well as applications of the methods.

STAT 746. Spatial Data Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 513 and STAT 643 or permission of instructor. The course will introduce graphical and quantitative analysis for spatial data. Topics include data on fixed-grids, point-referenced data, lattice data, point-pattern data and experimental design for spatial data collection. Students will be expected learn how to program in appropriate software packages.
STAT 775. Time Series Analysis II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 513 and STAT 675, or permission of instructor. Advanced study of time series analysis. Topics include multivariate time series, state-space models and GARCH models. Applications involve the use of a statistical software package.

STAT 791. Special Topics in Statistics. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be repeated for credit. Prerequisite: permission of instructor. A detailed study of selected advanced topics in statistics.

Operations research
OPER 527. Optimization I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. Introduction to optimization and mathematical programming. Course addresses fundamental concepts of optimization (such as optimality conditions and duality) as well as the construction, solution, analysis and application of linear programming and network models. Emphasis is placed on using software to solve problems as well as on understanding its underlying methodology. Integer programming models will be introduced. Students may not receive degree credit for both OPER 427 and OPER 527.

OPER 528. Stochastic Simulation. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: graduate status in mathematical sciences, systems modeling and analysis, or decision sciences and business analytics, or permission of the instructor. An introduction to stochastic discrete-event simulation. The course covers simulation modeling and programming in general-purpose languages (e.g., VBA for Excel) and (briefly) in specialized simulation environments (e.g., Arena, @Risk). The probability foundations of stochastic simulation of stochastic processes, random number and variate generation, variance reduction techniques, and proper design and analysis of the simulation experiment are emphasized. Applications are drawn from manufacturing, finance, logistics and service systems. Students may not receive degree credit for both OPER 428 and OPER 528.

OPER 591. Topics in Operations Research. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be taken more than once for credit. Prerequisite: permission of the instructor. A detailed study of selected topics in operations research.

OPER 627. Optimization II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: OPER 527. This course will address basic theory and algorithms for nonlinear optimization (unconstrained and constrained). Both theoretical foundations and practical implementations of optimization algorithms will be covered.

OPER 635. Network Models and Graph Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: OPER 527 or permission of the instructor. This course will focus on optimization models for network problems, as well as on the underlying graph theoretic structure for such models. Emphasis will be on solution procedures and applications with some discussion of related implementation issues. The course will concentrate on the study of polynomial-time algorithms for well-solved problems. May also include treatment of solution techniques for NP-hard network problems. Possible topics for the course include, but are not limited to, maximum flows/minimum cuts in networks, minimum spanning trees, minimum cost flows, matching and assignment, shortest path problems, traveling salesman problems and multicommodity flows.

OPER 636. Machine Learning Algorithms. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with graduate status in mathematical sciences, systems modeling and analysis, decision sciences and business analytics, or computer science, or by permission of the instructor. Includes an in-depth analysis of machine learning algorithms for data mining, equipping students with skills necessary for the design of new algorithms. Analyses will include framing algorithms as optimization problems and a probabilistic analysis of algorithms. Students will be exposed to current areas of research in the construction of data mining algorithms. Crosslisted as: STAT 636.

OPER 639. Practical Optimization. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: OPER 527. The application of optimization theory toward the solution of practical problems in operations research. The use and analysis of computer programs available to solve such problems. The algorithms used in these programs will be discussed from a practical and theoretical point of view.

OPER 641. Stochastic Simulation and Monte Carlo Methods. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 513 and either STAT 503 or STAT 613. Addresses the methodological foundation of applying stochastic modeling and simulation with a focus on introducing simulation concepts through examples, algorithms and experiments. Topics include simulation output analysis, input modeling, simulation optimization, steady-state simulation, variance reduction techniques, sensitivity analysis and Monte Carlo optimization.

OPER 643. Decision and Risk Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: graduate status in mathematical sciences, systems modeling and analysis, or decision sciences and business analytics, or permission of the instructor. This course presents the decision and risk analysis theory and methodology. Decision analysis applies to hard problems involving sequential decisions, major uncertainties, significant outcomes and complex values. The course includes: decision structuring with influence diagrams and decision trees; modeling uncertainty with subjective probabilities; sensitivity analysis and the value of information; and modeling preferences with utility functions. Decision and risk analysis applications in business and government are considered.

OPER 645. Queuing Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. This operations research course provides a development of some basic queuing systems. Such systems will include birth-death queues, as well as the M/G/I and GI/M/S queuing systems. Other topics may include the GI/G/I queues, overflow queues and some basic queuing networks.

OPER 647. Multiobjective Decision Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences, systems modeling and analysis, or decision sciences and business analytics, or permission of the instructor. Introduction to the mathematical foundations of multiattribute utility theory. Topics covered include: structuring objectives; tradeoffs under certainty; unidimensional utility theory; multiattribute preferences under uncertainty; preferences over time; and aggregation of individual preferences. Real world applications will be discussed throughout.
OPER 648. Systems Reliability Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. An introduction to engineering reliability and risk analysis, specifically failure data analysis, maintenance problems, system reliability and probabilistic risk assessment. Applications in computer science and engineering will include stochastic characterization of wear in hardware systems and the development of failure models for software systems. Decision problems such as the optimal maintenance of repairable systems and optimal testing policies for hardware and software systems will be examined. The analysis of risk through fault trees, event trees and accident precursor analysis also will be discussed. Crosslisted as: STAT 648.

OPER 649. Statistical Quality Control. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: graduate status in mathematical sciences or systems modeling and analysis, or permission of the instructor. Demonstrates how statistics and data analysis can be applied effectively to process control and management. Topics include the definition of quality, its measurement through statistical techniques, variable and attribute control charts, CUSUM charts, multivariate control charts, process capability analysis, design of experiments, and classical and Bayesian acceptance sampling. Statistical software will be used to apply the techniques to real-life case studies from manufacturing and service industries. Crosslisted as: STAT 649.

OPER 691. Special Topics in Operations Research. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be taken more than once for credit. Prerequisite: permission of the instructor. A detailed study of selected topics in operations research.

OPER 696. Applied Project. 1-3 Hours.
Semester course; 1-3 lecture hours (to be arranged). 1-3 credits. Up to three credits will be applied to the M.S. in Mathematical Sciences (operations research or statistics concentration) per section. Can be repeated for credit. Prerequisite: SSOR 690 or permission of the faculty advisor. Designed to allow students to apply concepts and theories learned in other courses to a practical situation. Includes the selection, written description, completion and written report of the project and a presentation of the findings. Students may not receive credit for both OPER/STAT 696 and OPER/STAT 698. Graded as Satisfactory/Unsatisfactory. Crosslisted as: STAT 696.

OPER 697. Directed Research. 1-3 Hours.
Semester course; variable hours. 1-3 credits. May be taken more than once for credit. Prerequisite: graduate standing. Supervised individual research and study in an area not covered in the present curriculum or in one which significantly extends present coverage. Research culminates with an oral presentation and submission of a written version of this presentation to the supervising faculty member.

OPER 698. Thesis. 1-3 Hours.
Hours to be arranged. 1-3 credits. A total of 3 or 6 credits may be applied to the M.S. in Mathematical Sciences/Operations Research. (A total of 3 credits for an expository thesis or a total of 6 credits for a research thesis.) May be taken more than once for credit. Prerequisite: graduate standing. Independent research culminating in the writing of the required thesis as described in this bulletin. Grade of S/U/F may be assigned in this course.

OPER 731. Discrete Optimization. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: OPER 527. Provides the theoretical background necessary to design and evaluate advanced solution techniques for discrete optimization problems. Topics include theory of polyhedra and valid inequalities for integer programming models, matchings, computational complexity, and sufficient conditions for integer programs to be polynomially solvable. Scheduling, packing, covering and routing models will also be examined.

OPER 732. Optimization Under Uncertainty. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: OPER 527; graduate standing in mathematical sciences or systems modeling and analysis; or permission of the instructor. Offers an exploration of issues concerning decision-making problems under uncertainty using mathematical programming tools. Topics addressed include modeling uncertainty in optimization models, two-stage stochastic programs with recourse, chance constrained programs, statistical inference in stochastic programs and robust optimization. Special attention is paid to the algorithms, approximation via sampling and applications.

OPER 736. Mathematics of Knowledge and Search Engines. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 541 or equivalent. Investigates the mathematics, methods and algorithms for searching for and extracting structures of interest (knowledge) from large and possibly high-dimensional datasets. The motivation is the rapid and phenomenal growth of the search engine (as demonstrated by Google) as a major tool for search on the Internet, which has impacted commerce, education and the study of social, financial and scientific datasets. The development of the mathematical and statistical learning algorithms behind these search engines has led to advances in how large, high-dimensional datasets can be effectively analyzed for the extraction of knowledge. Crosslisted as: STAT 736.

OPER 741. Advanced Stochastic Simulation. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 513, OPER 528 and either OPER 503 or 613, or permission of the instructor. This is an advanced-level course on stochastic modeling and simulation. State-of-the-art topics on simulation theory and methodology will be taught through lectures and guided literature review. Tentative topics include advanced simulation output analysis, simulation optimization, steady-state simulation, nested simulation, metamodeling, variance reduction (stratification, importance sampling, quasi-Monte Carlo, etc.).

OPER 743. Decision Analysis II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: OPER 643 or OPER 647. Introduces the current areas of research in the field of decision analysis, which applies to hard problems involving sequential decisions, major uncertainties, significant outcomes and complex values. Includes current research in decision structuring and representation, modeling uncertainty with subjective probabilities, modeling preferences with utility functions and modeling multiattribute preferences.

OPER 791. Special Topics in Operations Research. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be repeated for credit. Prerequisite: permission of instructor. A detailed study of selected advanced topics in operations research.
Statistical sciences and operations research

SSOR 690. Research and Communications Seminar. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with nine graduate credits in OPER and/or STAT courses and with permission of the instructor. Designed to help students attain proficiency in professional and academic communication and research in the context of statistics and operations research. The course focuses on the discipline-specific communication and research skills necessary to excel in careers or graduate studies in these disciplines.

Systems modeling and analysis

SYSM 681. Systems Seminar I. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in academic communication and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific communication and research skills necessary to excel in graduate studies in these disciplines.

SYSM 682. Systems Seminar II. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in professional communication and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific communication and research skills necessary to excel in professional careers in these disciplines.

SYSM 683. Systems Seminar III. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in literature review and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific literature review and research skills necessary to write an applied project, thesis or dissertation.

SYSM 697. Systems Research. 3 Hours.
Semester course; 3 credits. May be repeated for credit. Prerequisite: graduate standing in systems modeling and analysis. Supervised individual research and study. Research culminates with an oral presentation and submission of a written report to the supervising faculty member.

SYSM 780. Stochastic Methods in Mathematical Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 513 or STAT 613; and MATH 535. Covers commonly used stochastic methods in mathematical biology, including cellular physiology and related areas. Topics covered include stochastic differential equation models, applications of first passage time (escape time) and applications of density or master equations, diffusion in cells, stochastic ion channel dynamics, and cellular communication. Students will be expected to learn how to program in appropriate software packages.

SYSM 798. Dissertation Research. 1-12 Hours.
Semester course; variable hours. 1-12 credits. May be repeated for credit. Research and work leading to the completion of the Ph.D. dissertation in systems modeling and analysis. Graded S/U/F.