# Master of Science with a major in Data Science
# University of Delaware
# *Program Policy Statement*
# Version of October 26, 2020

## ***Part I. Program History***

### *A. Purpose*

A campus-wide Data Science Working Group (DSWG) was formed in 2016 to foster data science research on the University of Delaware campus. The DSWG organized several meetings and events over the course of 2017, and produced a white paper in autumn 2017. Those events, in no small part, inspired this degree program. The examples presented in the events made it clear that successful data science programs involve collaboration across multiple disciplines: generally this means statistics, computer and information sciences, and mathematics together with domain or application areas.

Data science is one of the fastest growing sectors in the US. According to "The QUANT CRUNCH How the demand for data science skills is disrupting the job market", there were more than 2,350,000 job listings for Data Science and Analytics (CSA) in 2015; and the demand for DSA jobs is projected to grow by 15% over the following five years, which translates to additional 364,000 new job postings. From "Investing in America's data science and analytics talent: The case for action," a BHEF/PWC report (pwc.com/us/dsa-skills), there were 58,151 ads for data science and analytics jobs in the Philadelphia-Camden-Wilmington area in 2015 alone. In that year, there were a similar number in Seattle, and around 70,000 in each of the Boston, Dallas and Atlanta. In the larger metro areas of New York, Chicago, Los Angeles, San Francisco, and Washington DC combined to have postings of about 750,000 such positions. It may be that this is at the upper end for estimates for jobs, but there is little doubt that these staggering numbers of positions are difficult for organizations to fill.

According to the global management consulting firm McKinsey, data-driven technologies will bring an additional $300 billion of value to the U.S. health care sector alone, and by 2020, 1.5 million more "data-savvy managers" will be needed to capitalize on the potential of data, "big" and otherwise. (Manyika, J. et al., 2011, "Big data: The next frontier for innovation, competition, and productivity." McKinsey Global Institute, http://www.mckinsey.com).

The importance of data science was recognized in the "Final Report from the National Science Foundation Computer and Information Science and Engineering Advisory Committee Data Science Working Group" (https://www.nsf.gov/cise/ac-data-science-report). Their recommendations include the creation of data science centers; to support the design and development of data science pedagogy and curricula; and to invest in both national and institutional infrastructure to support emerging Data Science research and education programs.

The MS in Data Science is as a professional masters with a flexible set of core requirements in statistics, mathematics and computer and information sciences with a range of possible application areas. It provides a solid background in the methods behind data science so that our graduates can go out into their fields and work well with data, and be better prepared for the next methods to come along to work with large and/or dynamic data sets.

The program will provide both the breadth of training, and the flexibility to apply them in different fields. The flexibility allows for training in different categories of positions in data science: data analysts (use mathematical, statistical and modeling techniques to solve problems), data engineers (design, build and maintain an organization's data and analytical infrastructure) and data scientists (create sophisticated analytical models to build new data sets and derive new insights from data).

Given the interdisciplinary nature of data science, the program exploits departmental and college cooperation. The main requirements of the program comprise courses from three departments (and colleges): the Department of Mathematical Sciences (DMS, in Arts and Science), the Department of Applied Economics and Statistics (AES, in Agriculture and Natural Resources) and the Department of Computer and Information Sciences (CIS, in Engineering). Two courses would be required from each department, with each having a small list from which to choose. The idea of this Master of Science in Data Science is to provide a foundation in these three areas, with electives in these areas or, where appropriate, electives from wide range of departments to give specific domain knowledge.

### *B. Current Status*

The program began admitting students for Fall 2018, and is expected to be reviewed for permanent status in 2023. The degree program was initially housed in the Department of Mathematical Sciences, wherein physical files and administrative help were located. The program is moving to the Graduate College beginning the Fall 2021 semester. Though this document governs the rules of the program, some current information such as events, elective courses offered, and so forth can be found on the program web page at www.msds.udel.edu.

### *C. Degree Offered*

The degree awarded to those who complete this program will be a Master of Science with a major in Data Science (MSDS). The MSDS is awarded in one of the College of Agriculture and Natural Resources, the College of Arts and Science, or the College of Engineering. The degree is also offered in combination with a limited number of Bachelor degrees as a "4+1" program. In that case, the background subjects are covered in the undergraduate degree (either through required or elective courses), and six credits of the MSDS course work count toward the Bachelor degree as described below.

## ***Part II. Admission***

### *A. Admission Requirements*

Applicants must submit all materials directly to the University Office of Graduate and Professional Education using the online admission process before admission can be considered. Admission applications are available at: https://grad-admission.udel.edu/apply/

The program admission process is completed as follows: Completed applications consisting of the online application, undergraduate/graduate transcripts, three letters of recommendation, and the written statement of professional goals and values, are reviewed by the Executive Committee. A grade point average (GPA) of at least 3.00 is preferred. Applications are evaluated based on a combination of record of academic achievement, recommendations, and the applicant's statement of professional goals and values. The Executive Committee will make admission decisions and assign accepted students to faculty advisors upon matriculation.

International applicants must submit official proof of English proficiency such as TOEFL or IELTS scores. The recommended minimum TOEFL score is 100 and/or IELTS of 6.5.

### *B. Background Requirements*

A Bachelor's degree from an accredited program is required for admission. A major in any of mathematics, applied mathematics, statistics, computer science or engineering, or a field of engineering is a good background for this program. Applicants for the combined Bachelors and MSDS degree program must complete the background requirements prior to beginning the MSDS course work (see the next section and section III.A.5 for more information). A minimal background outside of the above STEM majors should include at least one semester of

- multivariable calculus (MATH 243 or MATH 222 or equivalent),
- linear algebra (MATH 349 or equivalent),
- statistics and/or probability (MATH 350 or 450, or Math 205, or STAT 470 or STAT 471, or equivalent),

and at least two semesters of

- computer programming (data structures or CISC220 equivalent desirable).

Additional desirable courses include

- ordinary differential equations (MATH 302 or MATH 351 or equivalent),
- a first numerical analysis or methods course (MATH 353 or MATH 426 or equivalent),
- an algorithms course (CISC 320 or equivalent),
- a logic and programming course (CISC 304 or equivalent),
- and both probability and statistics courses (MATH 350 and MATH 450, or STAT 470 and STAT 471, or equivalent).

The applicant shall apply to the MSDS program directly, and shall specify a specialty at the time of application (CIS, AES or DMS). The executive committee makes a decision on the application

for this degree. If needed, the executive committee will consult with the specialty department for confirmation that the student is suitable to the specialty of the department. An advisor will be assigned to matriculated students, and the first semester courses shall be approved by the advisor prior to the start of that semester.

Three letters of recommendation from individuals familiar with the candidate's academic and/or professional background and capabilities are required. Candidates must also submit a personal statement describing how their academic, professional and personal background has prepared them to be successful in the MSDS program, and explaining how the completion of the MSDS will contribute to their professional goals.

***C. Combined Bachelor and MSDS 4+1 requirements***

Students who wish to be admitted to the combined Bachelor/MSDS 4+1 program (details in section III.A.5) should submit an application during the junior year of academic study toward an undergraduate degree at the University of Delaware. Interested students should consult with an advisor from the MSDS program about the courses to be taken in order to fill out the "Graduate Course Approval Form for 4+1 Admission Approval" from OGPE. After submitting that form, the student may then apply to the Bachelor/MSDS 4+1 program. At a minimum, the applicant must have a cumulative GPA of 3.2 and a GPA of 3.4 in their undergraduate major. For any Bachelor degree, the applicant must have completed the background requirements listed in Section II.B by the end of the fourth year of undergraduate study. Two letters of recommendation from University of Delaware faculty and academic transcripts must be submitted. Neither the GRE nor the TOEFL exam is required for 4+1 program applications.

***D. Application deadlines***

The application deadline for Fall admission is July 1; the deadline for Spring admission is December 1. Earlier applications are encouraged because space may be limited.

***E. Types of Admission***

Students may be admitted into the program in one of two categories as follows.

1) Regular Admission: Regular status is offered to students who meet all of the established entrance requirements.
2) Conditional Admission: Successful applicants are typically admitted conditionally because stated information is self-reported and uploaded documents are unofficial. Fulfilling the conditions stated on an offer of conditional admission by the first date of graduate coursework is critical, so the instructions stated on the letter must be followed carefully. Failure to clear all stated conditions by the start of graduate coursework may result in revocation of admission to the graduate program.

3) Provisional Admission: Provisional status is offered to applicants who are seeking admission to a degree program but lack specific prerequisites needed in the University of Delaware degree requirements. All provisional requirements must be met within the deadline given before regular status can be granted. Failure to meet the provisions by this deadline is grounds for dismissal from the program.

### *F. University Statement*

Admission to the MSDS graduate program is competitive. Those who meet the stated requirements are not guaranteed admission, nor are those who fail to meet all of those requirements necessarily precluded from admission if they offer appropriate strengths.

## ***Part III. Academic Degree: Master of Science with a major in Data Science (MSDS)***

### *A. Degree Requirements*

A total of 33 credits is required for the degree. If the student lacks background knowledge for one or more courses, prerequisite courses may need to be taken that do not count toward the degree.

1) Required Courses

a) At least six credits of core courses are required from the following list from DMS (each course is three credits):
   - MATH612 Solving Linear Equations and Optimization (F)
   - MATH637 Mathematical Techniques in Data Science (S)
   - MATH672 Vector Spaces (F)
   - MATH630 Probability Theory and Applications (F)

b) At least six credits of core courses are required from the following list from CIS (each course is three credits):
   - CISC621 Algorithm Design and Analysis (F/S)
   - CISC637 Database Systems (F/S)
   - CISC683 Introduction to Data Mining (F)
   - CISC684 Introduction to Machine Learning (S)

c) At least six credits of core courses are required from the following list from AES (each course is three credits):
   - STAT611 Regression Analysis (F)
   - STAT613 Applied Multivariate Methods (F)
   - STAT674 Applied Data Base Management (F/S)
   - STAT675 Logistic Regression (S)

d) A three-credit ethics course on data science, the permanent version of PHIL 667 "Ethics in Data Science and AI" or courses cross-listed with it, is required.

Credit for both STAT674 and CISC637 cannot be applied to the degree.

2) Electives

Up to 12 credits of elective courses may come from a variety of courses on campus with relevant application or quantitative content. An initial list of example courses is given in Appendix A. The courses must be at the 600 level or above for the home college from which the degree is awarded. A course from the required lists may be chosen as an elective provided that it has not already been used to satisfy the six core course requirement. The initial elective list is not meant to be exhaustive. The electives taken by the student must be approved by the advisor and the Executive Committee of MSDS. The student's choices of electives shall be approved by the advisor prior to registration and by the executive committee prior to the beginning of the last semester.

3) Non-thesis option

33 credits of course work are required. Up to three credits of Special Problem or Research can be applied toward the credit total. These Special Problem or Research credits may come from experience on campus or in industry (e.g., internships). Special Problem or Research credits must be related to the degree and must be approved by the advisor and the executive committee. Valid scholarly output from such credits are presentations (oral or poster), papers, reports or similar that demonstrate related work in the field.

4) Thesis option

Up to six credits can be used to do a MS thesis according the requirements of the department in which the student will take the degree. The University requirements for master's theses shall apply to the thesis in this degree. The committee for the thesis shall include three members with at least one member not from the specialty department.

5) Bx/MSDS 4+1 program

The MSDS can be obtained in conjunction with a limited numbers of Bachelor degree programs as a 4+1 combination. Here the x in Bx can be A for Arts, S for Science or other letters for other degrees. At the time of writing, the Bachelor degrees available are as follows. Any of the Bachelor degrees from the DMS may be combined with the MSDS: BA in Mathematics or Mathematics Education; BS in Actuarial Sciences, Applied Mathematics, Mathematics and Economics, Mathematics Education, or Quantitative Biology; or honors versions of any of them, HBx. Similarly, any of the Bachelor degrees from CIS, Electrical and Computer Engineering (ECE), Mechanical Engineering (ME), or Physics and Astronomy (DPA) are available for combining with the MSDS as a 4+1 program. From CIS, these are: Computer Science (BA, BS); Information Systems (BS); and honors versions (HBx). From ECE, these are: Computer Engineering (BCpE); Electrical Engineering (BEE); and honors versions (HBx). From ME, these are: Bachelor of Mechanical Engineering (BME), and the honors version (HBME). From DPA, these are: BS, BA, HBS, HBA options in each of Physics or Astronomy, as well as BA and HBA in Physics Education. Up to six credits from the graduate course work may be applied to the

Bachelor degree that come from the area of the undergraduate major. For example, mathematics courses may be applied to a major from DMS, computer science courses can be applied to a major from CIS, and electrical engineering courses may be applied to a major from ECE.

Students who wish to be admitted to the Bx/MSDS 4+1 program should submit an application during the junior year of academic study toward an undergraduate degree at the University of Delaware as described in section II.C.

6) Advisor and Program of Study

An advisor will be assigned prior to the start of the first semester of study for the MSDS. The first semester courses shall be approved by the advisor prior to the start of that semester. The student and the advisor will develop a program of study; the program of study submitted to the executive committee for approval prior to the end of the first semester of courses. For students accepted into the 4+1 program, an advisor for the MSDS will be assigned prior to the end of the second semester of the junior year of undergraduate study, and a program of study for the MSDS shall be approved before the end of that semester.

7) Changes to the Program of Study

Students may need to alter approved programs of study due to scheduling conflicts or the creation of new courses directly related to the student's goals. Students who wish to make minor changes to their program of study must obtain permission from their advisor. Major changes to the program of study, such as the substitution of one or more core courses, must be approved by the Program Committee. All changes in a previously approved program of study must be approved by the Program Director.

8) Transfer credits

Up to six credits may be transferred from courses applicable toward the degree, provided that the credits have not been applied to obtain a different degree. The transfer must be approved by the Executive committee, and if necessary, in consultation with the department that offers the (potentially) equivalent course.

9) Awarding the degree

The MS degree is awarded by the Dean of the Graduate College for this interdisciplinary degree. The executive committee shall approve the program of study of the MSDS prior to the student applying for the degree (i.e., the forms submitted prior to graduation).

***B. Timetable and satisfactory progress toward the degree***

1) Academic load and satisfactory progress

The MSDS program will follow the University of Delaware, Office of Graduate and Professional Education recommended policy for determining students' failure to make satisfactory progress towards degree

requirements and time limits for completion. Students may be enrolled on a full-time (9 credits per term) or part-time (fewer than 9 credits per term) basis.

2) Grade and GPA requirements

Students must pass all of the core courses with a minimum grade of B or better, and a grade point average (GPA) of 3.25 or better in the six core courses, to continue in the program. The student may repeat a core course one time in order to earn an acceptable grade for the degree. All graduate-numbered courses taken with graduate student classification at the University of Delaware are applied to the cumulative GPA. Credit hours and courses for which the grade is below B- do not count toward the degree even though the grade is applied to the overall GPA. Elective courses may not be repeated to apply to the degree.

3) Grievance procedures

Students concerned that they have received an unfair evaluation or have been graded inappropriately may file grievances in accordance with the student guide to University of Delaware policies. Students are encouraged to contact the program director prior to filing a grievance.

## ***Part IV. Assessment Plan***

### *A. Program*

The program will follow the Academic Program Review (APR) schedule, policies and procedures, established by the Provost's office and Faculty Senate. Data will be provided by the Office of Institutional Research and Effectiveness, in conjunction with faculty/student interviews, measures of scholarly productivity and alumni. Meetings will be held at least semi-annually to discuss curricular changes, review data, identify actions to strengthen the program, and establish timelines and assignments for responsibilities. The program will continue consultation with the Center for Teaching and Assessment of Learning to periodically assess learning outcomes, assessment criteria, and benchmarks for success.

### *B. Student Progress*

| **Assessment plan for students in the M.S. in Data Science** | | | | |
|---|---|---|---|---|
| **Objectives** | **Strategic Activities** | **Measures** | **Short-term Outcomes** | **Long-term Impact** |
| **1. Train students in a mix of statistics, math** | Recruit excellent applicants and matriculate | Number and demographic data of student applicants and | Retention and time to degree statistics | Students gain employment in data-science related fields, in domain area jobs |

| | | | | |
|---|---|---|---|---|
| **and computer science** | students with strong credentials | matriculated students. | | (e.g., energy, commerce, etc), or go on to more graduate school |
| | Course work covering the disciplines of probability, mathematics, statistics and computer programming and algorithms | Faculty evaluation of student progress in course work<br>Surveys of graduate students in the program and post-graduation | Students are prepared for subsequent coursework that requires theoretical and practical knowledge | Graduates enjoy long term success in government, industrial, commercial or academic careers. |
| **2. Provide training in data science techniques** | Course work in regression, statistics, multivariate analysis, logistic regression, data management, machine learning, optimization, algorithms, data mining and other approved courses including electives from domain areas | Surveys of students focusing on their experiences in these classes<br>Surveys of graduates to determine the utility of these classes to their career<br>Faculty evaluation of student progress in course work | Course work for the M.S. in Data Science degree helped students secure initial employment<br>Students and graduates report applying knowledge from courses to work settings | Graduates enjoy long term success in data science and domain area careers |
| **3. Provide experiential training in projects or internships to prepare students for the expectations of the workplace** | Case study approach in courses with real data and required analysis<br>Research or Special Problem courses using projects from academic and non-academic sources | Quality of the case study results in the courses.<br>Faculty evaluation of quality and scope of the research project.<br>Surveys of graduates to determine the utility of their | Case studies, Research and Special Problem courses force the student to apply the material in the class to real data.<br>A thesis, is that option is chosen, forces the student to master an area of | Graduates enjoy long term success in their careers |

| | | | | |
|---|---|---|---|---|
| | A thesis option, when chosen, requires synthesis of the knowledge and methods studied. | course experience to their career | use to the field, and develops strong writing skills. | |

## ***Part V. Financial Aid***

This is a professional master's program and students are expected to pay graduate tuition.

## ***Part VI. Program organization and administration***

The program was initially located in Mathematical Sciences within Ewing Hall. It is expected that the location will remain the same for the 21-22 academic year, but the program will be administered from the Graduate College.

### *A. Affiliated Faculty*

The affiliated faculty shall include the following: the executive committee; faculty interested in teaching courses for the MSDS program; faculty interested in offering projects and non-academic contacts for projects; faculty who will supervise theses for the degree; and administrators contributing any of the above to the program. The initial executive committee will accept the CV of interested faculty and approve or deny the application for affiliated faculty.

### *B. Director*

The Program Director will be elected by the executive committee and affiliated faculty, and may involve an interview process. The Program Director will typically be from one of AES, DMS or CIS, but other departments are possible from within the participating colleges provided that the candidate has experience with related courses, projects or subject matter. The approval of the Director Elect's home Department Chair with appropriate course release or other support for the position is required. The Program Director will serve for a three year term. Re-election requires a majority vote of the affiliated faculty that vote; the vote may be electronic. The initial appointment of the Program Director shall be made after an interview process that involves the department chairs of AES, CIS and DMS and the initial affiliated faculty. Those department chairs will make recommendations to the affiliated program faculty. Applications will include a cover letter stating interest in the position and plans for the program, and a complete curriculum vitae.

The responsibilities of the Program Director include:

1. Leading and overseeing the program;
2. Organizing and leading meetings of affiliated faculty and the Executive Committee;
3. Communicating as needed with the Graduate College, and other appropriate offices such as Professional and Continuing Studies;
4. Serving as first point of contact for issues arising with program students and faculty;
5. Organizing and managing the admissions process;
6. Approving all changes to programs of study;
7. Approving all changes in faculty advisors.

***C. Assistant Director***

The Assistant Director will be elected by the executive committee, and may involve an interview process. The Assistant Director will typically be from one of AES, DMS or CIS, but other departments are possible from within the participating colleges provided that the candidate has experience with related courses, projects or subject matter. The approval of the Assistant Director Elect's home Department Chair with appropriate support for the position is required. The Assistant Director will serve for a two-year term. Re-election requires a majority vote of the executive committee that vote; the vote may be electronic. The initial appointment of the Assistant Director shall be made after an interview process that involves the executive committee and the initial affiliated faculty. Applications will include a cover letter stating interest in the position and plans for the program, and a complete curriculum vitae.

The responsibilities of the Assistant Director include:

1. Leading and overseeing the advising of students;
2. Organizing the pairing of advisors with students;
3. Monitoring student progress toward the degree and informing the Director;
4. Organizing academic events for the MSDS students;
5. Ensuring timely information and submission of student forms and decisions;
6. Organizing graduation and other student celebrations.

***D. Executive Committee***

An executive committee consisting of one member from each of DMS, AES, and CIS (including the director), plus two to four at-large members from other departments.

The terms of the Executive Committee members will be staggered with two year terms for half of the committee (excluding the director). An Executive Committee member may serve two consecutive terms with an affirmative vote of the affiliated faculty.

Responsibilities of the Executive Committee include:

1. Making admissions decisions on students for each of Fall, Winter and Spring terms;
2. Matching students to faculty advisors;

3. Approving all new programs of study and major changes to existing programs of study, including transfer, special problem or research credits;
4. Identify contacts for projects and data for both on campus and off campus experiences;
5. Attend events as required for the program such as for recruiting and making contacts for projects and data;
6. Approve or deny applications for affiliated faculty.

### *E. Steering Committee*

A committee of select distinguished faculty as well as non-academic contacts from industry, commerce and government shall be formed to advise the executive committee and all others involved in the management of the program. They will be expected to meet at least annually to discuss and advise the program.

## ***Part VII. Appendices***

### *A. Elective Courses*

The design of this degree is flexible. Courses appropriate from the main departments, as well as a few others, are listed below as a sample. The list is not meant to be exhaustive. The electives taken by the student must be approved by the advisor and the Executive Committee of MSDS.

The list includes course number, title and in parentheses, typical semesters in which the course is offered (F=Fall, W=Winter, S=Spring). The typical semester of offering is subject to change.

1. Courses from the Department of Mathematical Sciences may come from the list of core courses, or from the following:
    - MATH600 Fundamentals of Real Analysis (F)
    - MATH602 Measure, Integration and Complex Variables (S)
    - MATH611 Introduction to Numerical Discretization (S)
    - MATH616 Modeling in Applied Mathematics (F)
    - MATH617 Techniques of Applied Mathematics (S)
    - MATH620 Introduction to Mathematical Finance (S)
    - MATH631 Introduction to Stochastic Processes (S)
    - MATH650 Algebra I (S)
    - MATH660 Introduction to Systems Biology (F)
    - MATH667 Topological Data Analysis (S)
    - MATH688 Combinatorics and Graph Theory (F)
2. Courses from the Department of Computer and Information Sciences may come from the list of core courses, or from the following:
    - CISC604 Logic in Computer Science (S)
    - CISC612 Software Design (S)
    - CISC636 Computational Biology and Bioinformatics (F)
    - CISC642 Introduction to Computer Vision (F)
    - CISC650 Computer Networks II (F/S)

- CISC664 Introduction to Network Security
- CISC665 Introduction to Cybersecurity
- CISC681 Artificial Intelligence (F/S)
- CISC841 Algorithms in Bioinformatics
- CISC844 Computational Biomedicine
- CISC849 Advanced Topics in Computer Applications (when related to data science/big data – requires approval of advisor)
- CISC861 Wireless Networks and Mobile Computing (F)
- CISC879 Advanced Topics in Architecture and Software Systems (when related to data science/big data – requires approval of advisor)
- CISC882 Natural Language Processing (F)
- CISC887 Internet Information Gathering

3. Courses from the Department of Applied Economics and Statistics may come from the list of core courses, or from the following:
   - STAT601 Probability Theory for Operations Research and Statistics (F)
   - STAT602 Mathematical Statistics (S)
   - STAT603 Vector Spaces and Optimization (S)
   - STAT608 Statistical Research Methods (F)
   - STAT612 Advanced Regression Techniques (S)
   - STAT617 Multivariate Statistics (F)
   - STAT618 Sampling Methods (S)
   - STAT619 Time Series Analysis (S)
   - STAT624 Advanced Topics in Statistics (S)
   - STAT656 Biostatistics (S)
   - STAT657 Statistics for Earth Sciences (F)
4. Courses from the Department of Civil and Environmental Engineering may from the following:
   - CIEG642 Advanced Data Analysis (W)
   - CIEG652 Transportation Facilities Design (F)
   - CIEG654 Urban Transportation Planning (F)
   - CIEG655 Civil Infrastructure Systems (F)
5. Courses from the Department of Economics in Lerner College may come from the following:
   - ECON801 Microeconomics (F)
   - ECON802 Macroeconomics (F)
   - ECON803 Applied Econometrics I (F)
   - ECON804 Applied Econometrics II (S)
6. Courses from the Center for Bioinformatics and Computational Biology may come from the following:
   - BINF644 Bioinformatics (F)
   - BINF694 Systems Biology I (F/S)
   - BINF695 Computational Systems Biology (F)
7. Courses from the School of Public Policy and Administration may come from the following:

- UAPP668 Government Budgets and Fiscal Federalism (F)
- UAPP684 Performance Management and Program Evaluation (F)
- UAPP689 Information Technology and Management of Public and Nonprofit Organizations (S)
- UAPP694 Financial Management in Public & Nonprofit Sectors (F)
- UAPP701 Public Policy (F/S)

8. Courses from the Department of Geography may come from the following:
   - GEOG670 Geographic Information Systems and Science (F)
   - GEOG671 Advanced Geographic Information Systems (S)
   - GEOG673 Select Technical Topics: GIS (F/S)
   - GEOG681 Remote Sensing (S)
9. Courses from the College of Education and Human ~~Resources~~ Development may come from the following:
   - EDUC812 Regression & Structural Equation Modeling
   - HDFS815 Research Issues and Designs
   - EDUC862 Randomized Field Trials in Education
   - EDUC865 Educational Measurement Theory
   - EDUC874 Multivariate Statistics in Education
   - EDUC873 Multilevel Models in Education
   - EDUC872 Advanced Educational Measurement
   - EDUC876 Latent Variables for Educational Research
10. Courses from the Department of Electrical and Computer Engineering may come from the following:
    - ELEG 630 Information Theory
    - ELEG 631 Digital Signal Processing
    - ELEG 815 Analytics I: Statistical Learning
    - ELEG 817 Large Scale Machine Learning
    - ELEG 845 Modern Machine Learning
11. Courses from the Department of Mechanical Engineering may come from the following:
    - MEEG 621 Linear Systems (F)
    - MEEG 677 Introduction to State Estimation (S)
    - MEEG 678 Introduction to Autonomous Driving (S)
    - MEEG 698 Stochastic Optimal Control (S)
    - MEEG 877 Sensing and Estimation in Robotics (F)
    - MEEG 890 Nonlinear Programming (F)
    - MEEG 895 Game Theory and Mechanism Design (F)
12. Courses from the Department of Physics and Astronomy may come from the following:
    - PHYS 616 Statistical Physics and Thermodynamics
    - PHYS 660 Computational Physics
    - PHYS 661 Data Science for Physical Scientists
    - PHYS 664 Machine Learning for Time Series Analysis

13. Courses from additional departments are likely to be added as they are requested by students or departments, and subsequently approved by the executive committee.

***B. Sample courses of study***

Some sample courses of study appear below. Some advanced classes may only be offered every other year.

Statistics Track:

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 |
|---|---|---|---|---|
| CISC621 | | MATH637 | Project or | MATH612 |
| STAT611 | | STAT674 | Industry | CISC683 |
| STAT613 | | STAT675 | Experience (3 cr) | STAT675 |
| | | PHIL667 | | |

Sample Computer Science Track, biomedical data analysis

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 | Spring 2 |
|---|---|---|---|---|---|
| CISC621 | CIEG642 | CISC684 | Project or | CISC637 | CISC841 |
| STAT601 | | STAT613 | industry | MATH630 | CISC844 |
| CISC683 | | MATH637 | experience (3 cr) | CISC636 | CISC879 |
| | | PHIL667 | | | |

Sample Computer Science Track, big-data-applications orientation

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 | Spring 2 |
|---|---|---|---|---|---|
| CISC621 | | MATH667 TopDA | Project or | CISC683 | CISC684 |
| MATH630 | | CISC637 | industry | STAT617 | STAT619 |
| STAT613 | | STAT675 | experience (3 cr) | CISC849 or CISC879 | CIEG642, CIEG655, ECON803 OR CISC879 |
| | | PHIL667 | | | |

Sample Computer Science Track, focus on text analytics

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 | Spring 2 |
|---|---|---|---|---|---|
| CISC621 | | MATH637 | Project or | CISC683 | CISC684 |
| MATH672 | | CISC681 | industry | CISC882 | CISC887 |
| STAT611 | | STAT613 | experience (3 cr) | CISC849 or 879 | Optional: CISC844 |
| CISC637 | | PHIL667 | | | |

Sample Mathematics Track: (need at least one more; TopDA = Topological Data Analysis)

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 |
|---|---|---|---|---|
| CISC621 | | CISC637 | Project or | MATH630 |
| MATH612 | | MATH637 | industry | MATH667 TopDA |
| STAT611 | | STAT613 | experience (3 cr) | MATH672 or MATH600 |
| | | PHIL667 | | |

Graph theory track:

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 |
|---|---|---|---|---|
| CISC621 | | MATH688 | Project or | MATH630 |
| MATH612 | | MATH637 | industry | MATH667 TopDA |
| STAT611 | | STAT613 | experience (3 cr) | CISC637 |
| | | PHIL667 | | |

Applications Track:

Possibilities for applications tracks could include: Psychology; Public Policy and Administration; the physical or life sciences; Education; Political Science; Engineering; and others.

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 |
|---|---|---|---|---|
| CISC621 | CIEG642 | STAT675 | Project or | CISC637 |
| MATH612 | | MATH637 | industry | UAPP668 |
| STAT611 | | STAT613 | experience (3 cr) | UAPP689 or CISC684 |
| | | PHIL667 | | |

| Fall 1 | Winter 1 | Spring 1 | Summer 1 | Fall 2 |
|---|---|---|---|---|
| CISC621 | CIEG642 | CISC637 | Project or | CIEG652 |
| MATH612 | | MATH637 | industry | CIEG654 |
| STAT611 | | STAT613 | Experience (3 cr) | CIEG655 |
| | | PHIL667 | | |

4+1 Track:

Two courses must be taken in the 4th year of undergraduate study; suppose those two are CISC 621 and Math 637. The following table applies for one year of subsequent graduate study for the non-thesis option.

| Fall 1 | Winter 1 | Spring 1 |
|---|---|---|
| CISC637 | STAT666 | STAT613 |
| MATH612 | | CISC849 |
| STAT611 | | MATH667 TopDA |
| CISC683 | | PHIL667 |