Master of Science with major in Data Science
University of Delaware
Program Policy Statement

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 proposed 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 is aimed at providing 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 proposed interdisciplinary Master of Science in Data Science degree provides necessary training in statistics, computer science, and mathematics, as well as domain (or application) knowledge to be successful in the data science job market. 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 will begin admitting students for Fall 2018, and is expected to be reviewed for permanent status in 2023. The degree program will initially be housed in the Department of Mathematical Sciences, wherein physical files and administrative help will be located.

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.

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. A minimal background outside of these majors should include at least one semester of

- multivariable calculus,
- linear algebra,
- statistics and/or probability,

and at least two semesters of

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

Additional desirable courses include

- ordinary differential equations,
- a first numerical analysis or methods course,
- an algorithms course,
- a logic and programming course,
- and both probability and statistics courses.

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. 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.

D. 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.

E. 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 30 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)

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

30 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) Advisor and Program of Study

An advisor will be assigned prior to the start of the first semester. 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.

6) 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.

7) 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.

8) Awarding the degree

The student can choose which department, and thus college, awards the MSDS. The primary departments are expected to be DMS, CIS, or AES, but other departments are possible. The department/subject of the degree may be awarded by that college under the following circumstances.

a) If the student does a thesis, then the department of the advisor may be the department and college of the degree.
b) If the student does a project course with an advisor, together with at least one other course from that department, then the student may be awarded a degree from that department and college.
c) If the student does neither a project nor a thesis, then the degree may come from the department (and college) from which the student took at least 4 courses.

Exceptions to the above policies may be granted by the executive committee. The executive committee shall approve the subject and any emphasis 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 and computer science	Recruit excellent applicants and matriculate students with strong credentials	Number and demographic data of student applicants and matriculated students.	Retention and time to degree statistics	Students gain employment in data-science related fields, in domain area jobs (e.g., energy, commerce, etc), or go on to more graduate school
	Course work covering the disciplines of probability, mathematics,	Faculty evaluation of student progress in course work	Students are prepared for subsequent coursework that requires	Graduates enjoy long term success in government, industrial,

	statistics and computer programming and algorithms	Surveys of graduate students in the program and post-graduation	theoretical and practical knowledge	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 Surveys of graduates to determine the utility of these classes to their career Faculty evaluation of student progress in course work	Course work for the M.S. in Data Science degree helped students secure initial employment 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 Research or Special Problem courses using projects from academic and non-academic sources A thesis option, when chosen, requires synthesis of the knowledge and methods studied.	Quality of the case study results in the courses. Faculty evaluation of quality and scope of the research project. Surveys of graduates to determine the utility of their course experience to their career	Case studies, Research and Special Problem courses force the student to apply the material in the class to real data. A thesis, is that option is chosen, forces the student to master an area of use to the field, and develops strong writing skills.	Graduates enjoy long term success in their careers

Part V. Financial Aid

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

Part IV. Program organization and administration

It is expected that this program be housed in a department or college office. It will most likely be located in Mathematical Sciences within Ewing Hall.

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.

The initial affiliated/joint faculty will include: Richard Braun (DMS), Hagit Shatkay (CIS), Tom Ilvento (AES), Nii Attoh-Okine (Civil Engrg), John McNutt (SPPA), Henry May (CEHD).

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 (degree-granting) 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 Program Committee;
3. Communicating as needed with the Office of Graduate and Professional Education, and other appropriate offices such as Continuing Education;
4. Serving as first point of contact for issues arising with program students and faculty;
5. Approving all changes to programs of study;
6. Approving all changes in faculty advisors.

C. 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.

D. 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 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		STAT 675	Experience	STAT675
			(3 cr)	

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

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

Sample Computer Science Track, focus on text analytics

Fall 1	Winter 1	Spring 1	Summer 1	Fall 2	Spring 2
CISC621		MATH441/641	Project or	CISC683	CISC684
MATH672		CISC681	industry	CISC882	CISC887
STAT611		STAT613	Experience (3 cr)	CISC849 or 879	Optional: CISC844
CISC637					

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

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

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

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