



Master of Science with a major in Data Science

University of Delaware
Program Policy Statement
Proposal

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Part I. Program introduction

The Master of Science in Data Science is a professional masters with a flexible set of core requirements in statistics, mathematics, ethics, and computer and information sciences. These provide a solid foundation in the principles behind data science so that our graduates can work well with current methods and tools while being prepared to learn the next generation of methods to come along. We combine this core with ample opportunities in elective courses to discover how data analysis is put into practice within fields across the university.

The program began admitting students in Fall 2018 and moved to the Graduate College beginning with the Fall 2021 semester. The M.S. in Data Science is awarded by the Graduate College. This document describes the official rules of the program.

Some departments at the university offer a dual-degree disciplinary Ph.D. with a concurrent M.S. in Data Science. While this document gives the requirements for the MSDS component of the dual degree, the admissions and administration of any dual degree program are governed by the department offering the Ph.D. degree.

Part II. Admissions

A. External admissions

Applicants who are not currently UD students must submit all materials directly to the Graduate College **by February 1** for admission in the succeeding fall semester. The following materials are required:

1. Online application at grad-admissions.udel.edu/apply
2. Transcripts of previous and current postsecondary education
3. Three (3) letters of recommendation
4. Curriculum vitae
5. Statement describing preparedness for the MSDS program and explaining how it will contribute to professional goals
6. For international applicants, official proof of English proficiency such as TOEFL (minimum score of 100) or IELTS (minimum score of 6.5)

A bachelor's degree from an accredited program (awarded or expected before the start of the MSDS program) is required for admission. Evaluations are based on a combination of record of academic achievement, recommendations, and the applicant's experience and statement. Applications are reviewed by the Admissions Committee only when submitted in full before the deadline, though

exceptional applicants may be offered provisional admission pending the timely receipt of some missing documentation.

B. Combined 4+1 Bachelor's and MSDS

Current UD students seeking admission to the Bachelor's/MSDS 4+1 program must apply **by May 1 before the final year of undergraduate study**. The following materials are required:

1. Online application using the Abbreviated 4+1 application form, *not* the general form
2. UD transcript
3. Graduate Course Approval Form for 4+1 Admission
4. Two (2) letters of recommendation from UD faculty

Applicants must consult with their undergraduate advisor and an MSDS representative, such as the Associate Director, to complete the required 4+1 Course Approval Form, which details how courses will be applied to satisfy both degrees. A cumulative GPA of at least 3.2 is required for admission.

C. Recommended educational background

A Bachelor of Science in mathematics, applied mathematics, statistics, computer science, or a field of engineering is a good preparation for this program. For those in other majors, the following subjects are highly recommended:

- multivariable calculus (equivalent to UD's MATH 243 or MATH 222),
- linear algebra (equivalent to UD's MATH 349),
- statistics and/or probability (equivalent to UD's MATH 350 or 450, or MATH 205, or STAT 470 or STAT 471), and
- two semesters of computer programming (though data structures, equivalent to UD's CISC220).

Additional helpful courses include:

- numerical analysis or methods (equivalent to UD's MATH 353 or MATH 426),
- algorithms (equivalent to UD's CISC 320), and
- logic and programming (equivalent to UD's CISC 304).

D. 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 those requirements necessarily precluded from admission if they offer appropriate strengths.

Part III. Regulations of the academic program for the 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.

Expected semester of course offering is given below (F = fall, S = spring, J = summer); these are subject to change.

1) Core requirements: 18 credits

a) At least six credits of core courses (2 courses) in PROBABILISTIC AND STATISTICAL FOUNDATIONS are required from the following list (each course is three credits):

- STAT 611 Regression Analysis (F/S/J)
- STAT 613 Applied Multivariate Methods (F)
- EDUC 812 Regression and Structural Equation Modeling (S)
- EDUC 874 Applied Multivariate Data Analysis (S)
- MATH 630 Probability Theory and Applications (F)

b) At least three credits of core courses (1 course) in DATABASES AND DATA MINING FOUNDATIONS are required from the following list (each course is three credits):

- *CISC 637 Database Systems (F/S)
- CISC 683 Introduction to Data Mining (F)
- *STAT 674 Applied Data Base Management (F/S/J)
- CPEG 657 Search and Data Mining (S)
- EDUC 875 Educational Data Mining (F)

**Only one of STAT 674 and CISC 637 may be applied toward the degree.*

c) At least three credits of core courses (1 course) in MACHINE LEARNING FOUNDATIONS are required from the following list (each course is three credits):

- CISC 684 Introduction to Machine Learning (S)
- #ELEG 815 Analytics I - Statistical Learning (F)
- #STAT 617 Multivariate methods and Statistical Learning (F)
- #MATH 637 Mathematical Techniques in Data Science (F/S)
- #SPPA 722 Machine Learning for Public Policy (S)
- #PHYS 661 Data Science for Physical Scientists (F, odd years)

Only two of these courses may be applied as required courses toward the degree.

d) At least three credits of core courses (1 course) in MATHEMATICAL AND COMPUTATIONAL FOUNDATIONS are required from the following list (each course is three credits):

- CISC 621 Algorithm Design and Analysis (F/S)
- \$MATH 612 Computational Methods for Equation Solving and Function Min (F)
- \$STAT 603 Statistical computing and optimization (convex optimization and algorithms) (S)

\$ Only one of MATH 612 and STAT 603 may be applied as required courses toward the degree.

e) Three credits (1 course) are required in ETHICS from the following list:

- PHIL 655 Ethics in Data Science and Artificial Intelligence (F)

2) Electives: 12 credits

Twelve (12) credits of elective courses may come from a variety of courses on campus with relevant application or technical content:

- A list of courses accepted as electives is given in Appendix A.
- Except for the restrictions noted in section III.1 above, courses from the core lists in that section that are not used to satisfy core requirements may be applied as electives.
- Other courses at the 600 level and above may be applied as electives if approved by the advisor and the Associate Director or Director of the MSDS prior to registration.
- Additional courses may be applied as described in the next two sections.

3) Experiential learning

Up to six (6) credits total from Internship (DASC 864), Special Problem (DASC 866), or Research (DASC 868) can be applied toward the elective credit total. These credits must be related to the degree. Valid scholarly output from such credits are presentations (oral or poster), papers, reports or similar products that demonstrate related work in the field.

These elective credits must be approved by the advisor and the Associate Director or Director by no later than the end of the free drop/add period of the semester in which the credits are taken.

4) Thesis option

If the student elects the thesis option for the degree, a minimum of six (6) credits of DASC 869 are required. Six credits of DASC 869 may be applied toward the total elective credit requirement, in which case no credits from DASC 864, DASC 866, or DASC 868 may be applied toward the requirement. All University requirements for master's theses shall apply to the thesis in this degree. The committee for the thesis shall consist of three members, with at least one whose home department is outside of the department of the advisor.

5) Bachelor's/MSDS 4+1 program

The MSDS can be obtained in conjunction with a number of specific UD bachelor's degree programs as a 4+1 combination to obtain both degrees in a total of 5 years. The eligible programs are listed in the UD catalog.

Up to six (6) credits from graduate (600- or 800-level) coursework taken as an undergraduate student may be applied to meet both the requirements of the bachelor's degree and the MSDS degree. Additional graduate credits that were not used to satisfy any bachelor's degree requirements may be transferred to meet the MSDS requirements.

Students who wish to be admitted to the Bachelor's/MSDS 4+1 program should apply during the junior (i.e., next-to-last) year of academic study toward an undergraduate degree at the University of Delaware, as described in section II.B.

6) Advisor and program of study

Students admitted from outside of UD work with the Associate Director to register for courses prior to the start of the first semester of study. An academic advisor is assigned prior to or at the start of the first

semester of study for the MSDS. Students admitted into the 4+1 program will be assigned an advisor for prior to the beginning of the final year of undergraduate study.

The student and the advisor develop a program of study for the entire path to the degree. This plan must be submitted to the MSDS program coordinator for approval by the Director before the opening of registration for the following spring or fall semester. The plan should be updated promptly by the student as needed to reflect any changes that are made in practice.

7) Changes to the program of study

A student may need to alter the approved plan of study due to scheduling conflicts, the offering of new courses, or evolution of the student's professional goals. Students are strongly encouraged to discuss changes to the plan of study with their advisors as early as possible. Any proposed changes must be submitted promptly to the program coordinator for approval by the Director.

Substitutions for any of the degree requirements in this document may be granted at the discretion of the Director, who may consult with the academic advisor, Associate Director, Executive Committee, or any other faculty member or administrator. Decisions are based entirely on individual circumstances and cannot be used to dilute or subvert the intended academic rigor and purpose of the degree.

8) Transfer credits

Up to six credits of approved courses completed at other universities may be transferred toward the degree, provided that the credits have not been applied to obtain any other degree. Each transfer must be approved by the Director in consultation with the department that offers a potentially equivalent course.

9) Awarding the degree

The MS degree is awarded by the Dean of the Graduate College. The Program Director shall approve the program of study for the MSDS on the student's Application for Advanced Degree (available online).

B. Satisfactory progress toward the degree

1) Academic load and satisfactory progress

The MSDS program follows the University and Graduate College policies 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 during any semester.

2) Grade and GPA requirements

Students must:

- receive a grade of B- or better in all core courses,
- receive a grade of C- or better in all elective courses,
- maintain an overall grade point average (GPA) of 3.0 or better, and
- meet any other grade requirements of the Graduate College or University.

A core course may be repeated one time to earn an acceptable grade. Elective courses may not be repeated for application to the degree. All graduate-level courses, including those that do not count toward the MSDS degree, taken with graduate student classification at the University of Delaware are applied to the cumulative GPA.

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 their advisor or the Director prior to filing a grievance.

Part IV. Assessment plan

A. Educational goals

1) Philosophy of the degree

The MS in Data Science at the University of Delaware aims to educate leaders in understanding and applying modern methods of data science to analyze problems of current interest in industry, government and academia. We aim to give the student a solid background in selected areas and the freedom to select relevant domain area courses. The domain areas may come from all over campus, such as from engineering, social sciences, public policy, geography, education, and the health sciences. The program is designed for flexibility. The following learning objectives aim to achieve these goals.

2) Educational goals

1. Demonstrate a mastery of foundational knowledge in data science through the successful completion of a diverse range of coursework encompassing multiple areas of domain *and* technical expertise.
2. Develop and apply data science techniques in one or more domain areas of interest via course projects, examinations, and/or a master's thesis.
3. Communicate data science techniques and findings to expert and non-expert audiences in written, discussion, visual, and oral presentation formats.
4. Demonstrate a deep understanding of ethics in data science and related technical tools through in-depth discussion and study of current ethical issues in the field.
5. Gain experiential training—via on-campus projects or external internships—in workflow management, technical collaboration, and professional accountability in preparation for the expectations of the workplace.

B. Program assessment

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.

C. 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, statistics and computer programming and algorithms	Faculty evaluation of student progress in course work 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	Surveys of students focusing on their experiences in these classes Surveys of graduates to determine the utility of these classes to their career	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

	electives from domain areas	Faculty evaluation of student progress in course work		
3. Provide experiential training in projects or internships to prepare students for the expectations of the workplace	<p>Case study approach in courses with real data and required analysis</p> <p>Research or Special Problem courses using projects from academic and non-academic sources</p> <p>A thesis option, when chosen, requires synthesis of the knowledge and methods studied.</p>	<p>Quality of the case study results in the courses.</p> <p>Faculty evaluation of quality and scope of the research project.</p> <p>Surveys of graduates to determine the utility of their course experience to their career</p>	<p>Case studies, Research and Special Problem courses force the student to apply the material in the class to real data.</p> <p>A thesis, if that option is chosen, forces the student to master an area of use to the field, and develops strong writing skills.</p>	Graduates enjoy long term success in their careers

Part V. Financial aid

There is no financial aid offered by the program for stipends or tuition.

Part VI. Appendices

A. Elective courses

See Part III for the regulations regarding elective courses, including exceptions made for courses not on this list. Some courses are not offered every year. Where known, indication is made of the typical semesters in which the course is offered (F=Fall, S=Spring, J=Summer), which is subject to change.

1. Courses from the Department of Mathematical Sciences may come from the list of core courses, or from the following:
 - MATH 611 Introduction to Numerical Discretization (S)
 - MATH 620 Introduction to Mathematical Finance (S)
 - MATH 631 Introduction to Stochastic Processes (S)

2. Courses from the Department of Computer and Information Sciences may come from the list of core courses, or from the following:
 - CISC 612 Software Design (S)
 - CISC 636 Computational Biology and Bioinformatics (F/S)
 - CISC 642 Introduction to Computer Vision (F)
 - CISC 665 Introduction to Cybersecurity (S) (also CPEG 665, ELEG 665, MISY 665)
 - CISC 681 Artificial Intelligence (F/S)
 - CISC 841 Algorithms in Bioinformatics
 - CISC 689 Topics in Artificial Intelligence
 - CISC 882 Natural Language Processing (F)
 - CISC 889 Advanced Topics in Artificial Intelligence
3. Courses from the Department of Applied Economics and Statistics may come from the list of core courses, or from the following:
 - STAT 602 Mathematical Statistics (S)
 - STAT 612 Advanced Regression Techniques (S)
 - STAT 619 Time Series Analysis (S)
 - STAT 622 Statistical Network Theory (F)
 - STAT 656 Biostatistics (S)
 - STAT 675 Logistic Regression (S/F)
4. Courses from the Department of Electrical and Computer Engineering may come from the list of core courses, or from the following:
 - ELEG 630 Information Theory (S)
 - ELEG 667 Machine Learning Systems (F)
 - ELEG 817 Large Scale Machine Learning (F)
 - ELEG 845 Modern Machine Learning (S)
5. Courses from the Center for Bioinformatics and Computational Biology may come from the following:
 - BINF 644 Bioinformatics (F)
 - BINF 694 Systems Biology I (F/S)
 - BINF 695 Computational Systems Biology (F)
6. Courses from the School of Public Policy and Administration may come from the following:
 - SPPA 667 Principles of Urban Science (F, even years)
 - SPPA 689 Information Technology and Management of Public and Nonprofit Organizations (S)
 - SPPA 701 Public Policy (F/S)
 - SPPA 721 Data Science Tools for Evidence Based Policy (F, odd years)
7. Courses from the Department of Geography and Spatial Sciences may come from the following:
 - GEOG 670 Geographic Information Systems and Science (F)
 - GEOG 671 Advanced Geographic Information Systems (S)
 - GEOG 673 Select Technical Topics: GIS (F/S)
 - GEOG 681 Remote Sensing of Environment (F)
8. Courses from the College of Education and Human Development may come from the following:

- EDUC 862 Randomized Field Trials in Education
 - EDUC 865 Educational Measurement Theory
 - EDUC 871 Advanced Structural Equation Modeling
 - EDUC 872 Advanced Educational Measurement
 - EDUC 873 Multilevel Modeling in Education (F)
9. Courses from the Department of Physics and Astronomy may come from the following:
- PHYS 607 Mathematical and Computer Algebra Methods in Physics (F)
 - PHYS 616 Statistical Physics and Thermodynamics (F)
 - PHYS 660 Computational Physics (S)
 - PHYS 664 Machine Learning for Time Series Analysis (S, even years)
 - PHYS 667 Computer Vision for Physical Sciences (F, even years)
10. 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 877 Sensing and Estimation in Robotics (F)
 - MEEG 890 Nonlinear Programming (F)
11. Courses from the Department of Civil and Environmental Engineering may come from the following:
- CIEG 642 Advanced Data Analysis (W)
 - CIEG 652 Transportation Facilities Design (F)
 - CIEG 654 Urban Transportation Planning (F)
 - CIEG 655 Civil Infrastructure Systems (F)
12. Courses from the Department of Economics in Lerner College may come from the following:
- ECON 803 Applied Econometrics I (F)

B. Sample courses of study

Some sample courses of study appear below as suggested paths through the curriculum. Note that some classes may not be offered every year.

Statistics emphasis

Fall 1	Spring 1	Summer 1	Fall 2
CISC621 STAT611 STAT613 PHIL655	MATH637 STAT674 STAT675 or STAT612	Project or Industry Experience (3 cr)	MATH612 CISC683 STAT675 or STAT622

Biomedical data analysis emphasis

Fall 1	Spring 1	Fall 2	Spring 2
CISC621 STAT601 CISC683 PHIL655	CISC684 STAT613 MATH637	CISC637 MATH630 CISC636	CISC841 CISC844 CISC879

Applications of big data emphasis

Fall 1	Spring 1	Fall 2
CISC621 MATH612 ELEG815 PHIL655	CISC684 CISC637 STAT611	CISC683 STAT613 CISC882 ELEG817

Text analytics emphasis

Fall 1	Spring 1	Fall 2	Spring 2
CISC621 PHIL655 STAT611 CISC637	MATH637 CISC681 STAT613	CISC683 CISC882 CISC642	CISC684 CISC887 Optional: CISC844

Mathematics emphasis

Fall 1	Spring 1	Summer 1	Fall 2
CISC621 MATH612 STAT611 PHIL655	CISC637 MATH637 STAT619	Project or industry Experience (3 cr)	MATH630 STAT613 MATH620 CISC 684

Public policy emphasis

Fall 1	Spring 1	Summer 1	Fall 2
CISC621 MATH612 STAT611 PHIL655	STAT675 MATH637 STAT613	Project or industry experience (3 cr)	CISC637 UAPP668 UAPP689 or CISC684

Civil engineering emphasis

Fall 1	Spring 1	Summer 1	Fall 2
CISC621 MATH612 STAT611 PHIL655	CISC637 MATH637 STAT613	Project or industry Experience (3 cr)	CIEG652 CIEG654 CIEG655 CISC684

Education emphasis

Fall 1	Spring 1	Summer 1	Fall 2
EDUC875 STAT613 CISC621 PHIL655	EDUC812 CISC684 STAT674	Project or Industry Experience (3 cr)	EDUC 873 EDUC 865 SPPA 721

Geospatial emphasis

Fall 1	Spring 1	Summer 1	Fall 2
PHIL655 STAT611 GEOG670	ELEG604 GEOG671 STAT613 GEOG681	STAT674	CISC621 PHYS661 CISC642 or PHYS664 or SPPA721

Social science emphasis

Fall 1	Spring 1	Summer 1	Fall 2
PHIL655 EDUC875 SPPA721	SPPA722 STAT611 EDUC812 CISC665	Project or industry experience (3 cr)	CISC621 SPPA701 EDUC862

Electrical and computer engineering emphasis

Fall 1	Spring 1	Summer 1	Fall 2
MATH630 ELEG605 ELEG815 STAT611	CPEG657 ELEG630 ELEG845	Project or industry experience (3 cr)	MATH612 ELEG817 PHIL655

4+1 Bachelor's/MSDS

Two courses may be applied to both the undergraduate degree and the MSDS. Two of them must be taken in the 4th year of undergraduate study; suppose those two are CISC 621 and MATH 637. It is very useful to take a third course prior to the +1 year; suppose this course is STAT 611. The following table applies for one year of subsequent graduate study for the non-thesis option.

Fall 1	Spring 1
CISC637 MATH612 PHIL655 CISC683	STAT613 CISC849 ELEG845 CISC684