

## COMPLEX SYSTEMS AND DATA SCIENCE PH.D.

All students must meet the Requirements for the Doctor of Philosophy Degree

### OVERVIEW

The Ph.D. in Complex Systems and Data Science provides a pan-disciplinary academic training for graduate students working on complex systems problems across all quantitative sciences. While the Ph.D. resides in the College of Engineering and Mathematical Sciences (CEMS), thereby providing a strong computational and theoretical training, the program’s scope is science-wide, encompassing natural, artificial, and sociotechnical systems. Depending on their chosen area of focus, students will work within and across research groups (potentially outside of CEMS) and be strongly connected with other students through co-location and regular student-led meetings and events. Students will be expected to generate and defend a scientifically important and socially meaningful body of work generally resulting in a minimum of three peer-reviewed journal papers and a dissertation. All students will receive a core training in empirical, computational, and theoretical methods for (1) describing and understanding complex systems thereby enabling them to, where possible, (2) predict, control, manage, and create such systems. Coursework will share a common core with the allied program Masters in Complex Systems and Data Science which include: (a) data acquisition, storage, manipulation, and curation; visualization techniques including state- of-the-art approaches to building high quality web-based applications; (b) finding complex patterns and correlations through, for example, machine learning; and (c) powerful ways of hypothesizing, searching for, and extracting explanatory, mechanistic stories underlying complex systems—not just how to use black box techniques.

### SPECIFIC REQUIREMENTS

#### Requirements for Admission to Graduate Studies for the Degree of Doctor of Philosophy

A Bachelor's degree and preferably a Master's degree in a relevant field and prior coursework in computer programming, calculus, linear algebra, probability, and statistics. Training in relevant aspects of physics (e.g., statistical mechanics) will be beneficial but not required. Applicants lacking one or more of these prerequisite areas may be accepted provisionally and will be required to complete an approved program of supplementary work within their first year of study. GRE scores are not required. Applicants will be evaluated based on their potential for excellence in research, as judged from their academic background, test scores, relevant experience and letters of recommendation. Students who are most likely to succeed and thrive in the program will be admitted.

Applicants whose native language is not English or whose formal education has been conducted in a language other than English must have a Test of English as a Second Language (TOEFL) score of 90 (Internet-based test) or above or an International English Language

Testing System (IELTS) score of 6.5 or above or a Duolingo score of 110 or above. To be considered for financial assistantship from the university, applicants must have an iBT TOEFL score of 100, an IELTS score of 7.0 or a Duolingo score of 120 above.

The student’s Studies Committee (see below) may recommend to the Dean of the Graduate College that a student be dismissed from the program if they receive two or more grades below a B (3.00), a designation of U in Dissertation Research, or if the Studies Committee deems that they are not making satisfactory progress towards their degree requirements (for which they must be able to provide sufficient documentation).

### MINIMUM DEGREE REQUIREMENTS

#### Minimum Degree Requirements

The P.h.D. has 5 milestones:

1. Completion of coursework
2. The comprehensive exams
3. The dissertation proposal
4. At least 2 published or accepted peer-reviewed publications prior to defending their dissertation, with a third at least in peer-review. These publications must be deemed of sufficient breadth, depth, and quality by their Graduate Studies Committee
5. The written dissertation and oral defense of the dissertation

#### COURSEWORK

A minimum of 75 credits of graduate study must be approved by the students graduate studies committee and successfully completed. All students must take a minimum of 30 credits of research and 30 credits of graduate coursework, of which at least 15 must be graded and may not count towards a Master’s degree (only courses with grades of B- or above are counted towards this minimum requirement and students with two grades below B are eligible for dismissal). Students may transfer credits for other universities or within UVM following standard UVM policies. Students will need to earn a minimum 3.0 GPA to graduate.

#### CORE COURSES (3 CREDITS EACH)

| Requirement Description       |                                | Credits |
|-------------------------------|--------------------------------|---------|
| CSYS 6701                     | Principles of Complex Systms 1 | 3       |
| or MATH 6701                  | Principles of Complex Systms 1 |         |
| CSYS 6020                     | Modeling Complex Systems I     | 3       |
| or CS 6020                    | Modeling Complex Systems I     |         |
| CSYS 5870                     | Data Science I - Experience    | 3       |
| or STAT 5870                  | Data Science I - Experience    |         |
| or CS 5870                    | Data Science I - Experience    |         |
| 2 of the following 3 courses: |                                |         |
| CSYS 6713                     | Principles of Complex Systms 2 | 3       |

|  |  |   |
|--|--|---|
| or MATH 6713   | Principles of Complex Systems 2              |   |
| CSYS 6990  | Special Topics (Modeling Complex Systems II) | 3 |
| or CS 6990   | Special Topics                               |   |
| STAT 6870  | Data Science II                              | 3 |
| All students are required to complete the 5 core courses, then may select their remaining coursework credits from the Complex Systems and Data Science Electives and the Concentration Track Electives in consultation with their advisor. |  |   |

Students will meet their course requirements by selecting appropriate coursework under the guidance of their studies committees. It is anticipated that most students would choose a subset of courses from a variety of complex systems and data science electives, including but not limited to:

**COMPLEX SYSTEMS AND DATA SCIENCE ELECTIVES (3 CREDITS EACH)**

| Requirement Description   |                                 | Credits                     |
|---|---------------------------------|-----------------------------|
| Dissertation Research Credits   |                                 | 3 to 9 credits per semester |
| CSYS 5766   | Gr Chaos,Fractals&Dymncal Syst  | 3                           |
| CSYS 6713   | Principles of Complex Systms 2  | 3                           |
| or MATH 6713  | Principles of Complex Systems 2 |                             |
| CSYS 6520   | Evolutionary Computation        | 3                           |
| or CS 6520  | Evolutionary Computation        |                             |
| CEE 7920  | Appld Artificial Neural Ntwrks  | 1-3                         |
| CSYS 7980   | Applied Geostatistics           | 3                           |
| or STAT 7980  | Applied Geostatistics           |                             |
| or CEE 7980   | Applied Geostatistics           |                             |
| STAT 5230   | Appld Multivariate Analysis     | 3                           |
| STAT 5290   | Survivl/Logistic Regression     | 3                           |
| STAT 5310   | Experimental Design             | 3                           |
| STAT 5350   | Categorical Data Analysis       | 3                           |
| STAT 5510   | Probability Theory              | 3                           |
| STAT 6300   | Bayesian Statistics             | 3                           |
| Any graduate-level course crosslisted in Complex Systems and Data Science, or other courses approved by the Complex Systems and Data Science Curriculum Committee |                                 |                             |

Students who do not make satisfactory progress toward their Ph.D. dissertation will be offered the opportunity to switch to the M.S. program, provided they meet the standards for the M.S.

Elective Tracks for the Ph.D. in CSDS match those provided for the M.S. in CSDS:

- CSDS: Energy Systems
- CSDS: Policy Systems
- CSDS: Biomedical Systems
- CSDS: Evolutionary Robotics
- CSDS: Environmental Systems
- CSDS: Transportation Systems
- CSDS: Distributed Systems Track
- CSDS: Self-designed named disciplinary track (requires approval of the CSDS curriculum committee)

**CONCENTRATION TRACK ELECTIVES**

Track Electives are considered relatively flexible and may be updated on a semester-by-semester basis, based on current course offerings and content and availability and may include special topics. See the Center’s website for current offerings.

**Comprehensive Examination**

Students will be tested via an extensive oral and/or written examination involving three faculty. Material will cover the three core courses and/or curriculum committee approved content.

**Requirements for Advancement to Candidacy for the Degree of Doctor of Philosophy**

Successful completion of the comprehensive exam and all required coursework.