

Graduate Study Manual

2017-2018

Electrical Engineering &
Computer Science Department

* Effective Fall 2017 - Summer 2018

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Welcome

As the Director of Graduate Studies (DGS) of the Department of Electrical Engineering and Computer Science (EECS) in Northwestern University's McCormick School of Engineering and Applied Science, it gives me great pleasure to welcome you. I wish you very successful and pleasant years at Northwestern University.

Sincerely,

Bryan Pardo, Associate Professor

EECS Department Director of Graduate
Studies Email: <pardo@northwestern.edu>

1. Overview

This manual provides detailed information about the educational opportunities in our graduate programs in electrical engineering, computer engineering, and computer science. It includes descriptions of our curricula, suggestions for coursework, various options, and information about our faculty, computer facilities, and student activities.

The document is in full compliance with the guidelines provided by The Graduate School (TGS) and often refers to sources available through their website.

1.1 General Notes

In addition to the world-class educational opportunities to work with top faculty while accessing a wealth of facilities, research labs, and libraries for intellectual growth, Northwestern University offers a variety of services which can assist different aspect of student life.

Wildcard:

The WildCARD is your photo identification card and can be used in almost every place that needs an identity verification on campus (library, recreational facilities, Norris University Center, campus, intercampus bus transit, etc.). It is issued by the WildCARD office in Norris University Center, underground level, Evanston campus, and at the University Services (support services) office in Abbott Hall, Room 100, Chicago campus. Lost or stolen ID cards are replaced for a \$15 fee. Broken or damaged cards will be replaced at no charge (providing the damaged card is returned).

Transportation:

There are three basic types of services available:

- Shuttle buses – there are several shuttles that operate in each of the Chicago and Evanston campuses (and between the two) upon presentation of a Wildcard. Detailed information is available at: <http://www.northwestern.edu/userservices/transportation/shuttles/>
- The Route 201 CTA bus which offers free service to Ryan field and to the Old Orchard mall in Skokie upon presentation of a Wildcard.
- U-Pass -- U-Pass is a collaboration between Northwestern and CTA (Chicago Transit Authority) based on fare cards called [Ventra](#), a contactless payment system that serves as a U-Pass. The card is issued at the beginning of every academic year, and it can be used 365 days a year on all CTA buses *and* trains.

Health Services:

Northwestern University provides a basic outpatient care and other primary-care services, and there are facilities in both Evanston and Chicago campuses. The Evanston location is at 633 Emerson Street (Searle Building). Per TGS regulations, every graduate student is legally required to have health insurance coverage. While it is provided for PhD students and a partial coverage is available for MS students, one may opt out of this coverage, as long as there is a proof of alternate coverage for the entire duration of graduate studies.

Counseling and Psychological Services (CAPS): (847-491-2151)

CAPS provides a set of core mental health services on campus, including clinical services, educational workshops, and consultation with faculty and staff as needed. Services are free for all students and available on both the Evanston (633 Emerson St) and Chicago campuses (Abbott Hall, 5th Floor, Suite 500, #710 N. Lake Shore Drive) (<http://www.northwestern.edu/counseling/>)

Personal Safety:

You should always be aware of your surroundings and avoid areas that have indication of being a potentially non-safe environment (e.g., poorly lit walkways and alleys at night). The University Police is on duty 24/7 and they are located at 1200 Davis St. in Evanston. In the case of emergency, always dial 911. Note that there are blue-light poles distributed across the University, which can also be used to contact the University police. The non-emergency contact number is 847-491-3456.

International Office (IO):

The IO is available to all the international students and its primary two roles are: (a) to provide guidance/advise for maintaining proper immigration status consistent with the laws of the United States; (b) to ensure compliance with those laws and help the students with various forms, such as OPT (Optional Practical Training) and CPT (Curriculum Practical Training). The IO is located at 630 Dartmouth place and the regular hours of operations are M-F, 10AM-5PM.

The Graduate School (TGS) – other resources and information

Every graduate student is assigned a counselor at TGS. The counselor monitors overall academic progress from the standpoint of TGS-based milestones, along with a satisfactory GPA, *etc.* Please be advised that most of the forms that concern completion of milestones are subject to a final approval by TGS in addition to being approved by your academic advisor and/or EECS department.

TGS is located at 633 Clark Street in Evanston, and its webpage: www.tgs.northwestern.edu contains a wealth of information pertaining to various aspects of students' life, some of which were described in the concise manner in this sub-section.

EECS Departmental Resources

Graduate students are expected to discuss all academic issues with their advisors first, in an open and constructive manner. Further help with every administrative aspect is provided by the EECS Graduate Student Affairs Office (Tech, Room L-351 – eecsgrad@northwestern.edu). The staff in the Graduate Office is experienced and can advise you on the course of action and promptly take the measures needed towards achieving a particular goal towards successful completion of your degree. Mailboxes maintained by the staff are provided for all graduate students for university-related postal-mail and packages only (not for personal use), and are located in the EECS Graduate Student Affairs Office. Each student is expected to show their WildCard upon pickup, and may only pick up their own mail, not that of another student. It should be made a matter of a habit to check for such mail at least once a month. Our mailing address is:

Department of Electrical Engineering and Computer Science
McCormick School of Engineering
2145 Sheridan Road, Rm L351
Evanston, IL 60208

The information about our courses is available at:

<http://www.mccormick.northwestern.edu/eecs/courses/index.html>

Graduate students should make it a habit of checking the above webpage when planning the courses to be taken in the subsequent quarters, and then proceed with a discussion with the respective academic advisors (and populating the data in the Graduate Students Tracking System (GSTS)).

Other useful information (e.g., forms, jobs-posting, announcements of visits by companies/recruiters, etc.) can be found at:

<http://www.mccormick.northwestern.edu/eecs/current-students/index.html>

Lastly: EECS organizes various social events throughout the Academic Year (bonfires, pizza-parties, GEECS coffee and bagels; etc.), for which announcement via email are made regularly.

1.2 General Admission Requirements

The primary objective of the admission process in the EECS Department is to determine an applicant's qualifications and judge the applicant's prospects for success in his/her desired program of study. To maintain a proper balance between department resources and the size of the graduate student population, we must limit offers of admission to the most qualified applicants. Thus, our admission process is highly selective and competitive in nature.

The deadline for **PhD** applications is **December 15** of the respective year, for the applicants who wish to be admitted to the program starting in the Fall Quarter of the subsequent academic year. The deadline for **MS** applications¹ is typically around **end of April** of the year during which an applicant plans to start in the Fall Quarter.

Requests for admission and financial aid for doctoral students are reviewed during Winter Quarter. It is the policy of the department that students begin their programs in Fall Quarter. Under special circumstances, students are allowed to begin in the Winter or Spring Quarter. A typical applicant is expected to have a B.S. in electrical engineering, computer engineering, computer science, or a related discipline from a recognized institution. Highly qualified candidates with other academic backgrounds may also be considered. The specific undergraduate preparation required for graduate study depends on the program and the area of specialization. An applicant with insufficient undergraduate preparation in any particular area, but well qualified in every other respect, may be required to take certain undergraduate courses as soon as possible after enrolling at Northwestern. A student would be informed of such a requirement at the time of admission, along with grade expectations.

The Graduate School (TGS) website <<http://www.tgs.northwestern.edu/admission/index.html>> provides a means to navigate through the application process for graduate study at Northwestern University. Importantly, note that all applicants for graduate study in the EECS Department must submit verbal, quantitative, and analytical scores from the Graduate Record Examination (GRE). If an applicant has already obtained an MS degree from a U.S. institution, then GRE scores are not needed for PhD admission. However, GRE scores are required for all applicants who wish to be considered for a university fellowship.

1.3 Financial Aid

PhD Students

The policy of the McCormick School is to admit only those students for whom financial support can be provided in the form of Northwestern (e.g. Cabell and Murphy) Fellowships, research assistantships, and teaching assistantships. Students who have financial support from outside institutions or government grants will also be considered for admission. However, if such internal (McCormick, EECS Department) or external (company, institutional fellowship, government) financial support is not provided, then the EECS Department will not recommend admission of the student to The Graduate School.

MS-Only Students

The EECS Department encourages MS-only students, especially from industry, to apply. However, the Department does not provide financial support to MS-only students. Such students can be supported by a company, government, or an external fellowship, or be self-supported. **MS students are not eligible for teaching assistantships or research assistantships.**

¹NOTE: MS applicants are *only* admitted for a Fall Quarter start date. This is to avoid any problems with the course sequence

1.4 Student Responsibilities

It is the responsibility of each graduate student to ensure that all the requirements of The Graduate School (TGS) and the EECS Department are met, given the program he or she selects; that necessary examinations are properly scheduled; and that deadlines dependent on current Northwestern University calendars are observed. The current procedures and degree requirements of the EECS Graduate Programs are detailed in this Manual.

Students should always consult with the EECS Department Student Affairs Office (Tech, L-351, eecsgrad@northwestern.edu) first to execute procedures, confirm requirements, and obtain paperwork for exams and various other procedures (e.g., visa related issues). In addition, students are strongly urged to consult regularly with their faculty advisors.

Official notices about degree program progress, financial aid and other important notices are sent to each student's official email and mail boxes.

Students are responsible for checking their official Northwestern <name>@u.northwestern.edu email accounts on a regular basis, no less than once a week.

Students are responsible for checking their official department mailbox on a regular basis, no less than once per month.

1.5 The Faculty Advisor & Planning the Program of Study

A graduate student (both MS and PhD) must plan his/her program of study in close consultation with a faculty advisor.

MS-Only:

For MS-only students an advisor assignment will be made at the time of admission. Unless the student wishes to change their advisor, this assignment is expected to continue until graduation. If a student decides to change advisors, their previous advisor and the Director of Graduate Studies (DGS) must be consulted, and the DGS must approve.

PhD:

For PhD students, an initial faculty advocate is assigned to each student at the time of admission to assist with planning the first academic quarter of study. This advocate is most likely a faculty member with research interests closest to those stated in the student's application, and therefore a strong candidate for serving as the student's eventual faculty advisor.

PhD students are required to have a permanent advisor by the end of their third quarter (typically spring quarter). To continue as a student in the EECS doctoral program beyond the third quarter of study, every PhD student must have an academic advisor with an appointment in EECS that is willing to serve as their advisor and who has an approved plan for funding.

Note that the student's advisor will serve as the primary contact with the EECS Department, and should be chosen to match the student's academic program of study and research interests (see [Section 5](#)).

If a PhD student decides to change advisors at any point in time during his/her studies, his/her previous advisor and the Director of Graduate Studies (DGS) must be consulted, and the DGS must approve.

In each quarter, the study plan should be approved by the student's advisor prior to registration. Graduate courses in electrical engineering, computer engineering, computer science, and related fields are described in this Manual and the bulletin of TGS.

The normal full-time program of graduate study is three units per academic quarter. The maximum permitted is four units. All students receiving financial aid in the form of fellowships, research assistantships, or teaching assistantships must register as full-time students.

1.6 Graduate Internships & Post-Graduation Employment

A graduate student wishing to combine research work with industrial experience may, with the permission of their advisor, elect to participate in the Crown Family Graduate Internship Program. This experience permits the student to gain a broader understanding of some problems that eventually could serve as the background for a thesis or project. For more information on the Crown Family Graduate Internship Program, see [Section 3.2.e](#) of this Manual.

International students who seek employment in the US upon graduating, who are on an F-1 visa, are in good academic standing, and have a valid I-20 should be aware that the visa status required for legal employment in the US after graduation is called OPT or CPT, and it **MUST BE APPLIED FOR 3-4 MONTHS BEFORE GRADUATION**. Without submitting this application in advance, you will not be able to transition smoothly from the F-1 student status to the OPT or CPT visa status, and any such interruption may delay or prohibit your employment with a US employer. The International Office (IO) assists students with collection and submission of the required documents. In addition to consulting with your advisor, you should also schedule a meeting at least one month in advance of the CPT or OPT submission deadline to ensure you have enough time to collect the needed documentation.

1.7 Department Administration

EECS Student Affairs Office – Tech L351

Program Assistant – Student Affairs

Kristen Sudman (847) 491-7092, Tech L351
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Program Assistant – Student Affairs

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EECS Department Administration

Business Administrator

Janice Perry, (847) 491-3376, Tech L358
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Chairman’s Assistant

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Financial Assistant, Keys, Orders

Carol Surma, (847) 491-3692, Tech L359
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Events Coordinator, Course schedule, Textbooks

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IT Computing Facilities – “root”

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Technical Support Staff (Root)

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Program Assistants

PA – CES & CAA Divisions

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PA – Signals & Systems Division (SigSys)

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PA – Cognitive Systems & Graphic & Interactive Media Divisions (CogSys & GIM)

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PA – Qualitative Reasoning Group (QRG)

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Financial Manager – Center for Quantum Devices (CQD)

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EE Labs

Electronics Specialist

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Electronics Technician

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Associate Director, MSIT

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Program Facilitator, MSIT

George Nejmeh, (847) 491-5931, 2311 Campus Dr., Room 1410
george@eecs.northwestern.edu

2. MS Program

This section discusses the details of the academic aspects of the process of obtaining MS degree with the EECS department. Unless otherwise specified, all the items pertain to all three of our majors (EE, CE and CS).

2.1 MS Degree Options

Each student pursuing an MS degree in the EECS Department must declare his/her intention to follow one of the degree plans (A, B, or C) summarized below. The student's declaration is subject to approval by his/her advisor. We recommend that this declaration be made during the second (Winter) quarter, but we require that it be made no later than May 1st of the third (Spring) academic quarter.

Plan A (Thesis MS Degree): In this plan, a student declares their intent to earn the MS degree by completing a formal thesis that reports substantial original research results. This entails completion of a minimum of two or maximum of three units of EECS 590 research credits under the supervision and guidance of the student's advisor. These units can be counted toward the 12-unit requirement for the MS degree. All requirements for the thesis MS, including coursework and approval of the thesis by the student's MS Examination Committee, must be successfully completed before the end of the seventh academic quarter (Spring quarter of the second year).

Plan B (Project MS Degree): In this plan, a student declares their intent to earn the MS degree by completing a project and writing a project report that contains results based on existing theory and techniques or experimental verifications. This entails completion of a minimum of one or maximum of two units of EECS 590 research credits under the supervision and guidance of the student's advisor. These units can be counted toward the 12-unit requirement for the MS degree. All requirements for the project MS, including all coursework and approval of the project report by the student's MS Examination Committee, must be successfully completed before the end of the sixth academic quarter (Winter quarter of the second year).

Plan C (Course MS Degree): In this plan, the student must satisfactorily complete 12 courses approved by the student's advisor. The choice of courses must represent a coherent program of study that prepares the student for advanced work in a specific field. All requirements for the course M.S degree must be satisfactorily completed before the end of the fifth academic quarter (Fall quarter of the second year).

Note that EECS 590 cannot be counted as a credit for a course-only based MS degree. The purpose of EECS 590 is to get students involved in research beyond the traditional course experiences. Hence, EECS 590 can only be applied towards the MS project option or the MS thesis option.

Time Limits: An MS student in either Plan A, B, or C who does not meet the plan's completion deadline stated above, and who does not successfully petition the EECS Department for an extension of that deadline, will be placed on academic probation for a maximum of two academic quarters. At that point, the Department retains the option to dismiss the student in question.

2.2 Advising and Course Requirements

Advising: Each MS student is assigned an academic advisor upon admission, based on the student's interests identified as part of his/her evaluation process. However, the student's preferences and interests may change, especially if s/he elects to follow the project or thesis degree plan, which entails the completion of one or more EECS 590 research units. This may require the student's transition to a new advisor. Such a transition involves the following steps: (1) The student notifies his/her current assigned

advisor; (2) An advisor-change form is completed and signed by both the current advisor and the new advisor, and is then returned to the EECS Department Student Affairs Office; (3) The EECS Department Student Affairs Office records the advisor change in the Graduate Student Tracking System (GSTS).

Each MS student must consult with his/her advisor before registering online for courses on CAESAR. Failure to do so could result in poor course selection that would delay completion of the student's MS degree, or even result in academic probation due to poor grades.

Course requirements: At least twelve (12) units of graduate-level credits are needed to complete the requirements for the MS degree – nine (9) courses at the 300-level or above, and a minimum of three (3) at the 400-level.

Typically, one unit of credit corresponds to a one-quarter course. With the exception of EECS 590 research, all courses must be taken for a grade. All coursework for the MS degree must be taken within The Graduate School (TGS) of Northwestern University, and must be completed with a composite grade- point average of B (3.0) or higher.

A few of our 300-level courses do not count towards the 9 credits at the 300-level. **EECS 317 cannot be counted toward the MS degree for CE and CS students** (the system-oriented version EECS 339 should be taken instead), whereas it can count for EE students. Similarly, **EECS 301 and 302 do not count toward any EECS MS degree**. They are intended for undergraduate students only (their 300-level code is to provide certain count towards the completion requirements for undergraduates). MS students must consult with their academic advisor before enrolling in courses to avoid taking courses that do not count towards their degree.

Courses completed for undergraduate credit at Northwestern or elsewhere cannot be repeated for graduate credit.

Up to three courses/credits at the 300 or above level from outside EECS can be applied to the MS degree, subject to the approval of the student's advisor and the Co-Director of Graduate Studies of the degree program.

To assure depth, every MS student is required to take at least three relevant courses at the 400 level. All 400-level EECS course are automatically deemed relevant. Courses at the 400-level taken outside EECS may be deemed relevant, subject to the approval of the student's advisor and the Co-Director of Graduate Studies of the degree program. It is important to consult with the academic advisor prior to enrolling in any course outside EECS.

EECS 590 research units do not count towards 400-level course credits.

EECS 499 Independent Study is suitable to obtain credit for work in specific subjects for which we have no regular courses. EECS 499 is also suitable to obtain credit for work on projects that are not directly related to the thesis or project required for the MS degree. EECS 499 is not intended to replace or augment required units of EECS 590 research for the MS thesis.

EECS course credit waivers for courses taken previously at another institution: An MS student may petition to have at most three EECS Department course credits waived based on the student's graduate level courses taken previously elsewhere. A petition for such a waiver must include complete documentation (e.g., syllabus, assignments/projects, etc.) of the content of a graduate level course from the student's previous institution that most closely matches the EECS Department course credit to be waived. The coordinator of this EECS Department course will then review the petition and make a recommendation. All such waivers are ultimately subject to the approval of the advisor, the EECS Research Group, and the EECS Director of Graduate Studies.

2.2.1 Electrical Engineering Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Electrical Engineering have the additional requirements described in this section.

Establishing Background: All MS Students in Electrical Engineering (including BS/MS students) must provide evidence of having sufficient background in the field as follows:

1. **Northwestern BS/MS students:** Must have completed the undergraduate EE core sequence (EECS 221, EECS 222, EECS 223, EECS 224, EECS 225) prior to or concurrent with beginning their Master's studies. This is the only option allowed for Northwestern BS/MS students.
2. **MS students new to Northwestern:** Must have completed a BS in EE degree at a previous university, the equivalent of the undergraduate EE core sequence (EECS 221, EECS 222, EECS 223, EECS 224, EECS 225) from another institution, or must take any courses missing from this EE core sequence prior to or concurrent with starting their Master's studies.

Coursework in Electrical Engineering: To ensure that students receive sufficient training in Electrical Engineering, 6 of the 12 required credits must be for courses taught by faculty whose primary appointment is in Electrical Engineering: EECS 303, 307, 308, 332, 333, 359, 360, 363, 374, 378, 379, 381, 382, 383, 384, 385, 388, 389, 390, 391, 398, 401, 402, 403, 404, 405, 406, 407, 409, 410, 411, 414, 418, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 463, 478, or an EECS 395/495 course taught by a faculty with primary appointment in Electrical Engineering, as listed here:

http://www.mccormick.northwestern.edu/eecs/people/faculty/index.html?academic_division=Electrical%20Engineering%20primary.

2.2.2 Computer Engineering Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Computer Engineering have the additional requirements described in this section.

Establishing Background: All MS Students in Computer Engineering (including BS/MS students) must provide evidence of having sufficient background in the field as follows:

1. **Northwestern BS/MS students:** Must have completed the undergraduate CE core sequence (EECS 203, EECS 205, EECS 214-1, EECS 221) prior to or concurrent with beginning their Master's studies. This is the only option allowed for Northwestern BS/MS students.
2. **MS students new to Northwestern:** Must have completed the equivalent of the undergraduate CE core sequence (EECS 203, EECS 205, EECS 214-1, EECS 221) from another institution, or must take any courses missing from this CE core sequence prior to or concurrent with starting their Master's studies.

Coursework in Computer Engineering: To ensure that students receive sufficient training in Computer Engineering, 6 of the 12 required credits must be from one of the courses described below (**499 Independent Study and 590 project/thesis credits cannot be counted towards the 6 core-CE course requirement**):

1. 300-level advanced undergraduate CE course listing:
 - a. Area 1: High performance computing - EECS 328, 333, 339, 350, 354, 358, 361, 362, 368, 452, 453;

- b. Area 2: VLSI & CAD - EECS 303, 355, 357, 391, 392, 395/495 (Advanced Low Power Digital and Mixed-Signal Integrated Circuit Design), 459;
 - c. Area 3. Embedded Systems - EECS 332, 346, 347, 369, 390, BME 384;
 - d. Area 4: Algorithm Design & Software Systems– EECS 321, 322, 336, 339, 343, 395; Design Project – EECS 347-1, 362, 392)
2. Any 300/400/500-level course taught by faculty with a primary appointment in CE, as listed here:
[http://www.mccormick.northwestern.edu/eecs/people/faculty/?academic_division=Computer Engineering primary](http://www.mccormick.northwestern.edu/eecs/people/faculty/?academic_division=Computer_Engineering_primary)
3. Temporary 395/495/396/496/397/497 courses from an approved list announced by the CE division annually and distributed to graduate students via email.

2.2.3 Computer Science Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Computer Science have the additional requirements described in this section.

Establishing Background: All MS Students in Computer Science (including BS/MS students) must provide evidence of having sufficient background in the field in one of 3 ways:

- 1. Northwestern BS/MS students:** Must have completed the undergraduate CS core sequence (EECS 101, EECS 111, EECS 211, EECS 212, EECS 213, EECS 214) **prior to beginning** their Master's studies. Students who have not completed the core sequence will not be admitted to the BS/MS program in CS. No course taken at another university can substitute for a core class, unless it is accepted as transfer credit towards an undergraduate degree program at Northwestern University. **This is the only option allowed for Northwestern BS/MS students.**
- 2. Preliminary Examination:** Prior to their first quarter of study, MS students in Computer Science must take a preliminary exam covering topics in our undergraduate CS core sequence (EECS 101, EECS 111, EECS 211, EECS 212, EECS 213, EECS 214). The preliminary exam is offered only once per year in the week before fall term. It is the responsibility of the students to arrive on campus in time to take this exam. This option is not allowed for BS/MS students.
- 3. Intensive Program Design Course:** Those who do not pass the preliminary exam must enroll in "EECS 295 Intensive Program Design" during their first quarter of study at Northwestern University and receive a grade of B or higher. This is a 2-credit course that teaches remedial skills that CS students should have prior to beginning a MS program. It is offered only in the fall quarter of each year and does not count towards the 12 required credits for the MS degree. This option is not allowed for BS/MS students. This option is not allowed for transfers from another program.

Coursework in Computer Science: To ensure that students receive sufficient training in Computer Science, 6 of the 12 required credits must be for courses on the CS technical electives list:

The following courses all count as CS technical electives: EECS 303, EECS 313, EECS 314, EECS 315, EECS 321, EECS 322, EECS 325, EECS 330, EECS 331, EECS 332, EECS 335, EECS 336, EECS 337, EECS 338, EECS 339, EECS 340, EECS 343, EECS 344, EECS 345, EECS 346, EECS 348, EECS 349, EECS 350, EECS 351-1, EECS 351-2, EECS 352, EECS 354, EECS 361, EECS 368, EECS 369, EECS 370, EECS 371, EECS 372, EECS 394, EECS 415, EECS 440, EECS 441, EECS 444, EECS 450, EECS 469, EECS 473-1, EECS 473-2, EECS 474.

All courses taught under the 396, 397, 496, and 497 numbers also count as CS technical electives.

Only three courses taught under the 395/495 course numbers count as CS technical electives: EECS 395/495 Art of Multicore Processing, EECS 395/495 Optimization techniques for machine learning and deep learning, EECS 395/495 Deep Learning from Scratch.

No other 395/495 course counts as a CS technical elective.

Other courses, if taught by faculty with a primary appointment in CS may count as CS courses. Consult with your advisor to confirm such a course counts as a CS course prior to registration. Faculty whose primary appointment is computer science are listed here:

http://www.mccormick.northwestern.edu/eecs/people/faculty/?academic_division=Computer_Science_primary

2.3 Residency Requirements

According to TGS, the minimum residency requirement for the MS degree is the equivalent of three quarters of full-time registration in graduate courses. Full-time registration is defined as three or four course units per quarter. Refer to TGS website for details about residency requirements:

<<http://www.tgs.northwestern.edu/about/policies/masters-degree-requirements.html>>

Note that the residency requirement also applies for the CPT (Curriculum Practical Training), which enables MS students to take a summer internship during their studies.

2.4 Resident Master's Study (TGS 588)

Registration for TGS 588 is open to those MS students who wish to devote their time to full-time research for one quarter. TGS 588 provides no accumulation of credit toward residency. TGS 588 is appropriate for students who have completed the 12-unit requirement for the MS degree, but have not completed all the details of the work required by the given project or thesis (e.g., experiments have not been completed by the deadline for applying for graduation), and wish to maintain full-time enrollment status. Students may register for TGS 588 in more than one quarter, but the Dean of TGS will review each TGS 588 registration beyond the first one to determine that the student is making reasonable progress toward completion of the MS degree.

2.5 Graduation Requirements

In order to receive the MS degree, a student must complete the Application for a Degree Form. To do this, take the following steps:

1. Go to CAESAR online and click on Self Service.
2. Click on the Application for a Degree tab and provide the requested information.
3. **Before clicking the SUBMIT button, print the page** and bring it to the EECS Department Graduate Office, Tech Room L351.
4. When the form is complete, click Submit.

To be eligible to receive the MS degree, students must have at least a 3.0 (B) grade-point average and no X or Y grades. No more than one-third of the total units presented for the MS degree may be EECS 499. EECS 590 is the only course for which the P/N option is acceptable in the MS degree program.

2.6 Final Examination

Students who have chosen Plans A or B (thesis or project) must pass a final exam to earn their degree. **Final exams are not required for a Plan C (course MS degree).** Students prepared to take their MS Final Examination must take the following steps **at least one week prior to the exam**:

1. Go to CAESAR online and click on Self Service.
2. Click on the MS Final Exam tab and provide the requested information.
3. **Before clicking the SUBMIT button, print the page.**
4. When the form is complete and printed, click Submit.
5. Bring the page you printed to the EECS Department Graduate Office, Tech Room L351.
6. Obtain and complete the **EECS Examination Request Form**, included at the end of this Manual and also online at <<http://eeecs.northwestern.edu/popular-forms>>. Follow the instructions on the form and obtain the required signatures.

7. The EECS Department conference rooms in either Tech or Ford suitable for your exam are shown at <<http://www.eecs.northwestern.edu/resources/451-reserve-a-conference-room>>. If you are using Outlook, you will be able to check the availability of these rooms via that server. Otherwise, simply send an email to <conf-res@eecs.northwestern.edu> with your reservation request. Be sure to verify that your committee members are available on the date of your exam, and that you have met all the other degree requirements of the EECS Department and The Graduate School, as detailed in this Manual.
8. Bring the Examination Request Form to the EECS Department Graduate Office at least one week prior to the exam date.

If the exam is open to the public, an announcement of the exam will be posted in the Department. Your file will be checked for any missing documents, grades, etc. The file and your EECS Examination Request Form will be given to your advisor prior to the exam and must be in the exam room for reference. After the exam, the form must be signed by all committee members. Your advisor returns the completed signed paperwork and your file to the EECS Department Graduate Office immediately upon completion of the Final Exam.

2.7 Transfer to a different MS program

Whether it is Computer Engineering, Computer Science, or Electrical Engineering, students admitted to an MS program in EECS are expected to complete the program of study to which they applied and were admitted. During the applications process, our admissions committee carefully reviews all the materials submitted, and students are admitted with a belief that they would succeed in the program they were admitted to. Only in very rare cases are MS students allowed to transfer to a different program within EECS.

Our MS programs have limited capacity and we only accept a small percentage of applicants. We cannot accept all those who wish to transfer to them from other programs at Northwestern. Only in very rare cases are transfers from an MS in another Northwestern department allowed.

All requests to transfer to one of our EECS MS programs must be approved by both the Co-director of Graduate Studies for the student's current degree program (in the case of a transfer within EECS) or current Director of Graduate Studies (if the student is in a program outside EECS) and the Co-director of Graduate Studies for the desired EECS program. The current advisor will also be consulted during the evaluation of the request. **Transfer is not guaranteed.** If approved, **transfers may require one or more additional quarters of study**, since curriculum progress towards the original program is one of the prerequisites of a transfer request.

Transfers to Computer Science can be particularly difficult, due to the program requirement for establishing appropriate background described in Section 2.2.3 of this document. This background requirement applies to all transfer students.

Transfer requests are accepted for review after the student has demonstrated success as evidenced by **at least one quarter of graded work** in the current degree program and, at the earliest, transfer requests may be placed in the 2nd (typically Winter) quarter - to be effective starting in the 3rd (typically Spring) quarter of their first year.

A student should request a program transfer no later than the date by which the students declare their degree plan: May 1 of the academic year of their admission, at the latest. In exceptional cases, requests for transfers will be considered after this date, however, they will be subject to extra review by the student's advisor, the Graduate Committee, and the Director of Graduate Studies.

Students who do not take any courses in the program to which they were admitted will not be considered for transfer until after they complete at least one quarter of graded work in the original program.

As a prerequisite, **a faculty member with primary affiliation in the desired program must express written consent to advise the student.** For Master's students who have selected the Thesis or Project option, this letter must explicitly state the advisor's willingness to advise the student on a multi-quarter research project. Furthermore, students must provide a valid justification for wanting to transfer their program of study that must also be validated by the new advisor.

Requests for program transfer should be signed by the students' academic advisor and submitted to the EECS Graduate Student Affairs Office and will be forwarded to the appropriate Graduate Chair(s) for evaluation. They will evaluate the transfer request by taking various factors into account. These factors include, but are not limited to:

- Success in the original program of study to which the student was admitted.
- The expected ability of the student to successfully complete graduate work in the desired program of study. Relevant evidence includes transcripts and work experience.
- The justification provided by the student for requesting a transfer. This justification must be based on something more substantial than a simple desire to change the title of the degree.
- The strength of the support expressed by a faculty member who has agreed to advise the student in the desired program.

2.8 Part-time Graduate Program

Graduate students may pursue their MS studies in the EECS Department on a part-time basis. For this purpose, the EECS Department schedules certain courses in the late afternoon. However, all of the MS degree requirements must be fulfilled, and it may not be possible to take all the courses at these late-afternoon time slots. Please discuss the details with the academic advisors and email the EECS Department Student Affairs Office <eecsgrad@northwestern.edu> for further information.

2.9 Pursuing a PhD After Being Admitted to the MS Program

There is no guarantee for admission into the PhD program for students who are currently in the MS-only program. However, successful students may be considered for a transfer. MS students are required to complete at least 2 quarters of residency in the MS-only program before they can be considered for a transfer to the PhD program. If a student is planning to apply to continue with the PhD program he/she should first contact the EECS Department Student Affairs Office (eecsgrad@northwestern.edu). The proper process for application for a transfer will be advised. Each student's case will be evaluated subject to the same procedures that apply to external PhD applicants.

2.10 Probation, Exclusion, and Appeal Processes

Failure to meet academic integrity standards (e.g. cheating on coursework), failure to meet the requirements for academic progress (e.g., maintaining a minimum of 3.0 GPA), and failure to meet milestones related to project or thesis work may result in The Graduate School placing a student on probation. In cases of milestones, students may petition to The Graduate School for an extension of the milestone's deadline if a convincing reason and evidence is provided. Failure to remedy the missing requirements by the given due date may ultimately result in exclusion from The Graduate School and the respective program.

Once a MS student is placed on probation, the EECS department reserves the right to review the student's case and subject the student to additional penalties during probation as relates to their standing in the EECS degree program including, but not limited to, loss of funding and/or exclusion from the EECS graduate program. For more information on probation and appeal processes for probation, please refer to **The Graduate School's guidelines**:

<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

3 PhD Program

This section covers the official **Milestones (3.1)** in a PhD student career and the **Registration (3.2)** requirements mandated by Northwestern University and the EECS Department for each year. In addition to the requirements outlined below, each Research Interest Group's Program of Study (PS) has additional requirements. See Section 5 (Programs of Study) of this manual for details.

3.1 Milestones

This section outlines the set of milestones that must be passed in the doctoral program of EECS. Any student not meeting the milestones will be considered not in good standing and therefore will be ineligible for fellowships, traineeships, teaching or research assistantships, and scholarships. Students who do not meet published requirements of satisfactory academic progress may be excluded from The Graduate School (TGS). Students who have taken time off for family or other approved leave will have appropriate accommodations made to adjust their milestones.

Student may view these milestones and the deadlines for completion in the Graduate Student Tracking System (GSTS). After logging into the GSTS Dashboard, the list of milestones can be viewed under "Show Profile > Milestones."

For additional information, see TGS PhD Degree Requirements webpage and TGS Satisfactory Academic Progress webpage:

<<http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html>>

<<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>>

3.1.a Selection of an Advisor for the PhD Dissertation

The purpose of a PhD dissertation is to train the student in the methods of research, that is, in how to formulate a research problem, how to proceed in a logical and systematic way to its solution, and develop results that are publishable in technical journals.

After starting the graduate program, students are urged to select their research topics as soon as possible. Identifying a research adviser is essential for academic progress. **PhD students are required to have a permanent advisor by the end of their third quarter (typically spring quarter). To continue as a student in the EECS doctoral program beyond the third quarter of study, every PhD student must have an academic advisor with an appointment in EECS and an approved plan for funding.** For more details see [Section 1.5](#) of this document. The student selects the subject of his/her research in close consultations with the advisor. Section 1.5 of this document. The student selects the subject of his/her research in close consultations with the advisor.

3.1.b Admission to Candidacy

As stated in TGS PhD Degree Requirements webpage noted above, a PhD student must be admitted to candidacy by the end of the third year of study, which falls on the last date of the 12th academic quarter.

A student failing to meet this milestone will be considered not in good academic standing, and therefore will be placed on academic probation, as per TGS Satisfactory Academic Progress webpage noted above.

Admission to candidacy requires meeting the academic requirements of the Program of Study of one of the six EECS Department Research Interest Groups (see Section 4 of this Manual) and passing the Qualifying

Exam of that Research Interest Group. Details of these requirements and Qualifying Exams appear in Section 5 of this Manual.

3.1.c Qualifying Examination

When you are ready to take a Research Interest Group's Qualifying Exam, fill in the **EECS Examination Request Form** available online at <<http://eecs.northwestern.edu/popular-forms>>. Instructions for scheduling an exam time and reserving a room are on this form. Note that the content of qualifying exams vary across different Programs of Study within the department. Section 5 specifies the requirements for each program of study

Verify the availability of your proposed faculty committee on the date chosen for your exam, and obtain all required signatures. Return the completed form to the EECS Student Affairs Office (Tech L351). The Student Affairs Office staff will submit the necessary information to TGS.

3.1.d Prospectus (Dissertation Proposal)

Students must have a prospectus (dissertation proposal) approved by a faculty committee no later than the end of the fourth year of study, which falls on the last date of the 16th academic quarter. A student failing to meet this milestone will be considered not in good academic standing and therefore will be placed on academic probation, as per TGS Satisfactory Academic Progress Guidelines (see link in Section 3.1). A minimum of three individuals must serve on this committee. At least two members of this committee, including the committee chair, must be members of the Northwestern University Graduate Faculty (see <<http://www.tgs.northwestern.edu/resources-for/faculty/>>). At least two members, including the committee chair, must be faculty in the EECS Department. See Section 5 of this Manual for any additional Research Interest Group requirements for the committee. Upon formation of the prospectus committee, the student should submit the PhD prospectus form through TGS Forms in the CAESAR website:

<http://www.northwestern.edu/caesar/>

3.1.e Dissertation and Defense

Every PhD candidate is required to prepare a dissertation indicating evidence of original and significant research. Read "Dissertation Formatting Guidelines" that can be downloaded from TGS at this link:

<http://www.tgs.northwestern.edu/documents/policies/dissertation-format-guidelines.pdf>

For the Final Exam, a student follows the same procedure as for the PhD Qualifier Exam (above in Section 3.1.b), although now the student clicks the PhD Final Exam tab in CAESAR.

Four weeks prior to the PhD Final Exam date, the student submits the EECS Examination Request form (available at <<http://eecs.northwestern.edu/popular-forms>>) **signed by all members of the committee.** The student must make sure that they have met all the degree requirements of the EECS Department as detailed in this manual and all requirements of Northwestern's Graduate School, as specified on their website at the link provided at the start of Section 3.1.

An announcement of the student's Final Exam is then posted in the EECS Department. The student's file is checked for any missing documents, grades, etc., that need to be completed for the Final Exam and awarding

of the PhD degree. This file and the *Report of the Committee on Examination of Candidate form* is given to the student's adviser prior to the Final Exam and must be in the examination room for reference. Upon conclusion of the Final Exam, this *Report* must be signed by all of the committee members. Then, the adviser immediately returns the completed and signed paperwork to the EECS Student Affairs Office.

Once the PhD dissertation has been approved by the committee, and all subsequent edits and revisions are completed by the student, the student must submit the dissertation online via the ProQuest website: <<http://www.etdadmin.com/cgi-bin/home>>. At this point, a TGS Student Services representative reviews the formatting and confirms via email that the dissertation is acceptable or notifies the student if changes need to be made.

3.1.f Teaching Requirement

In February 2014, the McCormick School of Engineering approved the following PhD teaching requirement effective with the PhD class matriculating in Fall 2014:

- (1) All students earning a PhD degree from a McCormick program must meet one of the following requirements:
 - (a) Serve as an instructor of an undergraduate course, or
 - (b) Serve as a full-time teaching assistant (20 hours a week) in an undergraduate course for at least one quarter, or
 - (c) Serve as a part-time teaching assistant (6-8 hours a week) in an undergraduate course for at least three quarters, or
 - (d) Meet a Departmental teaching requirement that has been approved by The Graduate School.
- (2) Teaching assistant positions must involve some face-to-face contact with students (office hours, lab or problem session, lecturing) in addition to grading.

In addition to options (1a), (1b), and (1c) listed above, PhD students in the EECS Department can choose to satisfy McCormick's teaching requirement by registering for two quarters of *Teacher Trainee* (TT) duties. Each TT quarter's work assignment involves a half-time teaching assistantship with some additional class involvement beyond grading homework or staffing a help desk. Typically, during the academic quarter, the TT prepares and presents one class lecture or designs one new homework assignment.

First-time TT students should register for EECS 545 (Teaching Experience) to receive credit for their effort. Second-time TT students should register for EECS 546, which is zero credit but does place on their transcript recognition of their contribution.

Note that a PhD student cannot be both a full-time teaching assistant and a TT in the same academic quarter. Also, registrations in EECS 545 and EECS 546 are only for TT students.

Also note that a student **will not be able to graduate until one of the teaching requirements listed above is fulfilled**. When a student files his/her thesis proposal, the student must also file a form listing what part of the teaching requirement has been fulfilled at that point and what, if any, teaching requirement has yet to be fulfilled.

3.2 Registration and Course Requirements

3.2.a The Graduate School Requirements

TGS requires that all full-time PhD students must complete eight academic quarters of residency consecutively over two years, including summers. All students must complete at least nine graded courses at Northwestern and maintain a B average (3.0 GPA). During academic quarters in which students are not enrolled full-time in graded coursework, they may register for EECS 590 Research to maintain full-time study. See TGS' General Registration Policies webpage:

<http://www.tgs.northwestern.edu/about/policies/general-registration-policies.html>

Typically, students take three courses per academic quarter and may not take more than four courses per quarter. After these requirements are met, a student may begin registering for TGS 500. After their fifth year, students who are without funding may register for TGS 512.

Any alterations in the residency timeline can be managed through Leave of Absence requests. Per TGS Continuous Registration Policy (see TGS General Registration Policies webpage link on in the preceding paragraph), all PhD students must be registered at Northwestern University in each of the Fall, Winter and Spring terms until all degree requirements have been completed, including dissertation submission to The Graduate School.

Students receiving financial support (assistantships or fellowships) must be registered as full-time students, including summer quarters. Such students must also maintain satisfactory academic progress, as per TGS Satisfactory Academic Progress Guidelines (see Section 3.1 for the link).

3.2.b Common EECS Course Requirements

The EECS Department requires 15 units of coursework for the PhD Coursework includes EECS 499, EECS 510, and EECS 545, but not EECS 590 (research). At least 6 units should be at the 400 or 500 levels, not counting EECS 545 and EECS 546 (these are the two credits one can earn for teaching).

EECS 590 research units make up the remainder of the units beyond the EECS Department courses taken by the student and any credits given for prior coursework elsewhere.

A PhD student's adviser or EECS Research Interest Group may require more than the minimum number of courses. In such cases, the number of EECS 590 research units will be reduced correspondingly.

EECS 499 is reserved for projects that are not directly related to the research required for the PhD thesis or for readings in specific subjects for which the EECS Department has no regular courses. EECS 499 is not intended to replace or augment the required units of EECS 590 research for either the MS or PhD degrees. Computer engineering and electrical engineering students are limited to two units of EECS 499.

3.2.c Programs of Study

Each student must complete a Program of Study that specifies additional course requirements beyond the common requirements for all EECS doctoral students. Section 4 specifies the requirements for each program of study.

3.2.d Petitioning for Course Credit or Substitution

A PhD student may petition to have at most six (6) EECS Department course credits waived, based on graduate level courses taken previously elsewhere. This petition must include complete documentation (e.g., syllabus, assignments/projects, etc.) of the content of the course from the student's previous institution that most closely matches the EECS Department course credit to be waived. The coordinator of this EECS Department course will then review the petition and make a recommendation. All such waivers are ultimately subject to the approval of the advisor and the EECS Director of Graduate Studies.

3.2.e Internships during Graduate Study: The Crown Family Graduate Internship Program

PhD candidates who wish to conduct an internship in industry can do so by participating in the Crown Family Graduate Internship Program. This opportunity permits the doctoral candidate to gain practical experience in industry or in national research laboratories in areas closely related to his/her research. This internship can provide significant positive impetus to the thesis effort and may provide a basis for future employment. The program's intention is to promote continuing collaboration between Northwestern University and the participating organization.

Students elect the graduate internship option in the latter stages (e.g., third year) of the PhD study. The student is generally paid by the participating sponsor and works full-time for either three, six, or nine months with that sponsor. An appropriate position is located with the help of the student's PhD adviser and the associate deans of Graduate Studies and Research and Industry/Academic Affairs.

Students who wish to take advantage of this internship opportunity and earn academic credit need to sign up for The Graduate School General Curriculum 799-510 *Crown Family Graduate Internship* course for 0 units. A prerequisite for this course is a written approval of the PhD adviser. Students may register for this course for no more than three academic quarters and no more than two consecutive academic quarters.

International students participating in this program must apply for Curricular Practical Training (CPT) authorization for any off-campus internships. "Off-campus" is defined as any internship that takes place outside of Northwestern University. For more information on applying for CPT, please visit the International Office's website:

<http://www.northwestern.edu/international/living-working/student-employment/curricular-practical-training.html>

International students may register for TGS General Curriculum 799-510 *Crown Family Graduate Internship* during the summer quarter in which they spend their summer internship. At the end of the summer internship they must present their adviser with a written report.

For more details about the Crown Family Graduate Internship Program, contact the McCormick School's Associate Dean for Graduate Studies and Research or visit the following URL:

<http://www.mccormick.northwestern.edu/students/graduate/fellowships-internships/crown-family.html>

3.3 Probation, Exclusion, and Appeal Processes

Each quarter, students are expected to make satisfactory academic progress. Satisfactory academic progress is defined, in part, as meeting the requirements set by The Graduate School:

<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

Students are also expected to meet additional EECS requirements for satisfactory progress, as follows:

- Students found to be guilty of academic misconduct (e.g. cheating on coursework, or plagiarism of research) are defined as failing to make satisfactory academic progress.
- PhD students are required to have a permanent advisor by the end of their third quarter (typically spring quarter). To continue as a student in the EECS doctoral program beyond the third quarter of study, every PhD student must have an academic advisor with an appointment in EECS and an approved plan for funding. If a doctoral student has NO ADVISOR by the last day of a given quarter, or if the current advisor has notified the student and the Director of Graduate Studies of unsatisfactory research progress during a given quarter, this will constitute failure to make satisfactory academic progress, as defined by the program.
- Students are required to make satisfactory progress towards their thesis as evaluated by their thesis advisors.

Failure to meet requirements for satisfactory progress may result in The Graduate School placing a student on probation.

Students may petition to The Graduate School for an extension of a milestone's deadline if a convincing reason and evidence is provided. Failure to remedy the missing requirements by the given due date may ultimately result in exclusion from The Graduate School and the respective program.

For more information on probation and appeal processes for probation, please refer to The Graduate School's guidelines.

Once a PhD student is placed on probation, the EECS department reserves the right to review the student's case and subject the student to additional penalties during probation as relates to their standing in the EECS degree program including, but not limited to, loss of research assistantship (RA) funding, loss of departmentally funded support such as teaching assistantships (TA), loss of and/or exclusion from the EECS graduate program.

Students who fail to make satisfactory academic progress according to the EECS Program requirements in a given quarter will be put on probation for the following quarter. The student must use the probationary quarter to seek an alternate advisor or improve progress to receive a report of satisfactory progress with their current advisor. At the end of the probationary quarter, if the student has secured an advisor who can report satisfactory progress, the student will be removed from probationary status. Otherwise the department may make a recommendation of exclusion (dismissal) to The Graduate School. No further funding from the department or advisor will be provided to the student after the end of the probationary quarter.

4 Doctoral Programs of Study (PS)

General PhD requirements for Northwestern University (e.g. residency requirements, grade requirements, deadlines to reach milestones) are discussed in Section 3 of this manual. This includes information on common course requirements across all EECS doctoral Programs of Study.

In addition to the common requirements, every EECS doctoral student must select a degree area in which they complete a Program of Study (PS) under a faculty member that specializes in that area. Each program has specific requirements for the coursework, qualification exam, and dissertation prospectus. The EECS Department offers the following Programs of Study.

PhD in Electrical Engineering	4.1 Solid State & Photonics
	4.2 Signals & Systems
PhD in Computer Engineering	4.3 Computer Engineering
PhD in Computer Science	4.4 Computer Systems
	4.5 Computing, Algorithms, and Applications
	4.6 Cognitive Systems
	4.7 Graphics & Interactive Media

Each subsection that follows describes one program of study.

4.1 Solid-State and Photonics (Electrical Engineering)

Research Area Description:

Solid-state engineering focuses primarily on the science and technology of semiconductors for quantum structures and devices operating from the ultraviolet up to far infrared. Quantum devices are fabricated using the most advanced semiconductor synthesis technologies (MOCVD, MBE, gas source MBE, etc.), as well as microfabrication techniques (high-precision photolithography, e-beam evaporation, RTA, reactive-ion etching, etc.). The quantum devices are fully tested at each step in the fabrication process using advanced characterization techniques (diffraction, SEM, TEM, photoluminescence, Hall, etc.) Most of the research is performed within the Center for Quantum Devices (CQD), in a clean-room environment similar to what is found in industry. These quantum devices are in high demand by today's applications. Ultraviolet lasers and photodetectors are needed for astronomy, space communications and the monitoring of engines and heat sources. Red, green and blue (RGB) solid-state lasers are needed for high-brightness full-color displays and optical data storage (CD, DVD). High-power 0.808 μm , 0.98 μm , 1.3 μm , and 1.5 μm lasers and VCSELs are needed for medical applications and fiber optical communications. Infrared lasers (e.g. quantum cascade lasers), photodetectors (e.g. QWIPs), and focal plane arrays (FPAs) are needed for chemical analysis and night vision.

Optical systems and technology focuses on microcavity lasers, nanostructures, quantum and nonlinear optics, integrated optics, fiber optics and infrared waveguide devices, fiber-optic communications, and imaging through turbulence. Special emphases include: applications of novel quantum amplifiers in optical communications, imaging, and cryptography; devices for terabit per second WDM and TDM optical networks; and applications of computational techniques in integrated and nonlinear optics.

Faculty: Aydin, Grayson, Gu, Ho, Khalili, Kumar, Mohseni, Razeghi, Shahriar, and Yuen

The courses in this area are divided into Core Courses and Area-Specific Courses as follows:

PhD Coursework

Core Courses (Group A)

Each student is required to take **five** of the following ten core

courses:

EECS 382	Photonic Information Processing
EECS 383	Fiber-Optic Communication
EECS 388	Microelectronic Technology
EECS 401	Fundamentals of Electronic Devices
EECS 402	Advanced Electronic Devices
EECS 403	Quantum Semiconductors
EECS 404	Quantum Electronics
EECS 405	Advanced Photonics

EECS 406	Nonlinear Optics
EECS 411	Fundamentals and Applications of Special Relativity

Area-Specific Courses (Group B)

Elective courses in Solid-State and Photonics include:

EECS 333	Introduction to Communication Networks
EECS 381	Electronic Properties of Materials
EECS 384	Solid-state Electronic Devices
EECS 385	Optoelectronics
EECS 389	Superconductivity and its Applications
EECS 407	Quantum Optics
EECS 409	Semiconductor Lasers
EECS 414	Advanced Topics in Quantum Electronics
EECS 422	Random Processes in Communications and Control I
EECS 423	Random Processes in Communications and Control II
EECS 424	Noise and Fluctuation in Physical/ Engineering Systems
EECS 425	Quantum Electronics II–Noise, Modulation, and Quantum Properties of Laser Emissions
EECS 427	Optical Communications
EECS 428	Information Theory
EECS 429	Selected Topics in Quantum Information Science and Technology
EECS 454	Advanced Communications Networks
ESAM 411	Differential Equations of Mathematical Physics

With approval of their advisers, students can also take advanced courses (400-level) in Applied Mathematics, Physics and Astronomy, and Materials Science and Engineering, to fulfill the requirements of the Area-Specific Courses.

PhD Qualifying Examination

Photonics Option: For PhD students in the Photonics subgroup Program of Study (PS), the PS evaluation will be made by the Solid-State and Photonics PS Committee, appointed by the group director, on the basis of the following criteria:

- (1) the student's performance in coursework;
- (2) the student's performance in research, and
- (3) an oral exam.

The oral examination requirement can be bypassed if so deemed by the student's adviser.

The oral examination is conducted by a team selected by the PS committee and consists of at least three faculty members with expertise in the examination area. Some of the committee members can be faculty members from outside the EECS Department. The exam is offered once each year, and students must sign up for the exam with the director of the PS committee. A student is given two attempts to pass the PS evaluation. However, each student must get the PS evaluation done by the end of the student's second year in order to continue in the PhD program. Extension of this deadline for up to one year may be granted by the EE Co Director of Graduate Studies if requested by the student's adviser.

SSE Option: For PhD students in the Solid-State Engineering (SSE) subgroup, the PS evaluation, the student's adviser approves the exam and selects the qualifying exam committee members from experts in the field. At least three committee members must be from the EECS Department. The committee evaluation is based on the student's performance in coursework, an oral presentation, and a written proposal detailing the student's future research plans. The qualifying exam must be approved no later than just before the beginning of the fourth year of study (or end of third year).

PhD Prospectus

In addition to the PS evaluation, a student must get a thesis prospectus approved by the end of the fourth year. The procedure for this approval is as follows. The student selects three faculty members, one of which must be his/her adviser, for the thesis committee. The student produces a written proposal and makes a presentation to this committee. Following an evaluation of the written proposal and the performance of the student during the presentation, the committee decides on approving the prospectus. A student is given two attempts to receive this approval.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](#). Dissertations not conforming to these instructions will not be accepted: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.2 Signals & Systems (Electrical Engineering)

Research Area Description:

Communications, Networks, and Control focuses on communications, telecommunications and communication networks, and control theory. Specific areas of study include: mobile wireless multi-user communication, estimation and detection, wireless networks, resource allocation in communication networks, data network protocol design, network performance modeling and analysis, nonlinear and robust control, and stochastic hybrid systems.

Signal Processing focuses on the digital representation and algorithmic manipulation of speech, audio, image and video signals. Specific topics within this general area include: image and video processing; recovery and compression; multimedia signal processing; filter design and rank-order operators; image and video transmission; medical and biomedical signal processing; medical imaging; and, algorithms for medical instrumentation.

Faculty: Argall, Berry, Butz, Freeman, Guo, Honig, Katsaggelos, Lee, Pappas, Sahakian, Tumblin, Wei, C.-H. Wu, Y. Wu, and Yuen

Core Courses

All students must take the following four core courses:

- EECS 307 Communications Systems
- EECS 359 Digital Signal Processing
- EECS 410 System Theory
- EECS 422 Random Processes in Communication and Control I

Elective Courses

Each student must select three from the following list of seven courses:

- EECS 332 Digital Image Analysis
- EECS 333 Introduction to Communication Networks
- EECS 360 Introduction to Feedback Systems
- EECS 378 Digital Communications
- EECS 420 Digital Image Processing
- BME 383 Cardiovascular Instrumentation
- BME 402 Advanced Systems Physiology

Area-Specific Courses

In addition, each student must complete a sequence of courses in an area of specialization according to the recommendation of the advisor. These courses may be in Signals & Systems and other areas. Elective courses in Signals & Systems may include:

EECS 363	Digital Filtering
EECS 374	Introduction to Digital Control
EECS 380	Wireless Communication
EECS 418	Advanced Digital Signal Processing
EECS 420	Digital Image Processing
EECS 421	Multimedia Signal Processing
EECS 423	Random Processes in Communications and Control II
EECS 426	Signal Detection and Estimation
EECS 427	Optical Communications
EECS 428	Information Theory
EECS 432	Advanced Computer Vision
EECS 454	Advanced Communication Networks
EECS 478	Advanced Digital Communications
EECS 485	Local Area Networks
BME 384	Biomedical Computing
BME 402	Systems Physiology

PhD Program of Study Evaluation

The Signals & Systems Program of Study (PS) evaluation will be done by the Signals & Systems PS Committee on the basis of a student's performance in coursework, research, and the Signals & Systems PS written exam. The PS exam consists of two parts. The first part of the exam covers communication systems (EECS 222 and EECS 307), signal processing (EECS 359), linear systems (EECS 410), and probability and random processes (Math 310 and EECS 422). All students are responsible for all materials in the first part of the exam (the core exam). The second part of the exam (elective) covers digital image analysis (EECS 332), communication networks (EECS 333), control (EECS 360), digital communications (EECS 378), image processing (EECS 420), and cardiovascular instrumentation (BME 383; also offered as EECS 395/495). Each student is responsible for three of the six areas in the second part of the exam.

The PS Exam and corresponding evaluation are offered twice per year at the end of the Fall and Spring Quarters, generally on the Monday (core) and Tuesday (elective) of the week immediately following final exam week. Students must sign up for the PS Exam with the EECS Graduate Office. Students can choose between the Fall and Spring exams, and they will be given two attempts to pass the evaluation. However, each full-time student must pass the evaluation by the end of the student's second year to continue in the PhD program. Part-time students must pass the exam by the end of their third year.

PhD Prospectus

In the Signals & Systems Group, the prospectus is the student's proposal defense. The proposal is a written document describing the student's PhD research topic, with background and prior work and proposed work. The proposal defense is an event during which the student presents the proposal to

their PhD committee who then decide whether or not to pass the student either conditionally or unconditionally. Upon passing the prospectus the student then completes the research and writes and eventually defends the PhD thesis.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](#). Dissertations not conforming to these instructions will not be accepted: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.3 Computer Engineering

Research Area Description:

Areas of study in the Computer Engineering fall into four main categories: analysis and design of integrated circuits, computer architecture, high-performance and parallel computing, and embedded systems. Example subtopics within each category follow.

Analysis and design of integrated circuits: design verification; integrated circuit synthesis; model order reduction; and physical design of integrated circuits.

Computer architecture: application-specific programmable processors; power-aware microarchitectures; reconfigurable architectures; and reliable high-performance processor design.

High-performance and parallel computing: compilers and applications; high-performance storage and parallel I/O; and ultra-scale architectures and software.

Embedded systems: embedded system synthesis; mobile, wireless, and ubiquitous computing; operating systems; and power optimization.

Faculty:

Primary Affiliation: Choudhary, Gu, Hardavellas, Hester, Joseph, Ogrenci-Memik, Memik, Zhou, Zhu

Secondary Affiliation: Chen, Dinda, Sahakian

Program of Study for Computer Engineering (CE)

A CE student must take the following two core courses:

EECS 361: Computer Architecture

EECS 336: Design and Analysis of Algorithms

In addition, a student must choose three of the following six tracks and take at least two courses from each chosen track. EECS 361 and EECS 336 can help fulfill the track requirement. A course that is listed in two different tracks can fulfill both track requirements. Additional 300-level classes and a 400- level and above courses from the EECS Department can fulfill track requirements with the consent of the advisor.

A. Digital Design & VLSI

EECS 303 Advanced Digital Logic Design

EECS 355 ASIC&FPGA Design

EECS 357 Introduction to VLSI CAD

EECS 391 VLSI Systems Design

EECS 346 Microprocessor System Design

EECS 459 VLSI Algorithmics
EECS 395/495 Advanced Low Power Digital and Mixed-Signal IC Design

B. Architecture

EECS 361 Computer Architecture
EECS 368/468 Programming Massively Parallel Processors with CUDA
EECS 452 Advanced Computer Architecture
EECS 453 Parallel Architectures

C. Software and Data Engineering

EECS 351 Introduction to Computer Graphics
EECS 221 Programming Languages
EECS 322 Compiler Construction
EECS 339 Introduction to Database Systems
EECS 343 Operating Systems
EECS 455 Distributed Computing Systems

D. Parallel and Distributed Computing

EECS 358 Introduction to Parallel Computing
EECS 368/468 Programming Massively Parallel Processors with CUDA
EECS 455 Distributed Computing Systems
EECS 333 Introduction to Communication Networks
EECS 467 Parallel and Distributed Database Systems
EECS 453 Parallel Architectures

E. Numerical Computing

EECS 328 Numerical Methods for Engineers
ES_APPM 446-1 Numerical Solution of Partial Differential Equations

F. Algorithms

EECS 332 Digital Image Analysis
EECS 336 Design and Analysis of Algorithms
EECS 390 Introduction to Robotics
EECS 459 VLSI Algorithmics

EECS 457	Advanced Algorithms
IEMS 452	Combinatorial Optimization
IEMS 457	Integer Programming

PhD Qualifying Examination

A PhD student is automatically admitted into the candidacy after completing 9 courses and obtaining a GPA of 3.5 or higher. If previous graduate-level coursework completed at another institution was transferred, up to 3 of these courses can be used to contribute to the GPA calculation subject to the approval of the advisor and CE co-DGS. If a student does not meet the GPA criterion upon completion of 9 credits, a committee of three faculty with Primary Affiliations in Computer Engineering proctors an oral exam of the student in the immediately following academic quarter to determine whether the student can be admitted to the candidacy. This committee is formed by the advisor of the student. A student failing this exam will be excluded from the program.

PhD Prospectus

In addition to the Program of Study evaluation, a student must get a thesis prospectus approved by the end of the fourth year. The procedure for this approval is as follows. The student selects three faculty members, one of which must be his/her adviser, for the thesis committee. The student produces a written proposal and makes a presentation to this committee. Following an evaluation of the written proposal and the performance of the student during the presentation, the committee decides on approving the prospectus.

The prospectus committee is formed according to the following rules:

1. There are at least three members who currently have full-time faculty appointments at Northwestern University. At least two of these must be faculty members of the EECS Department. At least two (including the chair) must be members of the Graduate Faculty of Northwestern.
2. With the approval of the Department Chair, there may be one additional voting member of the committee from outside Northwestern. This person should be an expert in the area of the student's research. The Department Chair may request a resume from this outside member before the appointment.
3. Others may be invited to attend the examinations as nonvoting members of the committee.

If a PhD candidate changes his/her adviser and/or research topic after taking the PhD Oral Qualifying Examination, the student may be required to take another oral examination on the new research topic.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation). Dissertations not conforming to these instructions will not be accepted: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.4 Computer Systems (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see Section 3 of this document. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in Section 3.1 of this document.

Research Area Description

Research in Systems includes a broad range of topics, including (but not limited to) data mining, database systems, network security, programming languages, program development environments, network analysis; network protocols, peer-to-peer networks, resource virtualization and ubiquitous computing.

Affiliated Faculty

Fabian Bustamante, Yan Chen, Christos Dimoulas, Peter Dinda, Jennie Duggan, Robby Findler, Aleksandar Kuzmanovic,

Course Requirements

Breadth in Computer Science beyond Systems: Before taking qualifiers, each should have taken at least one course in each of the following areas: Theory, Artificial Intelligence, and Interfaces. Courses that satisfy those requirements are listed below.

- Theory: EECS 328, 335, 336, 356, 357, 457, 459. We strongly recommend that students become familiar with algorithms at least to the level of EECS 336.
- Artificial Intelligence (AI): EECS 325, 337, 344, 348, 349. We strongly recommend that students become familiar with core AI and machine-learning topics as described in EECS 348 and 349.
- Interfaces: EECS 330, 332, 351, 352, 370

Breadth in Computer Systems: The expectation for students is that they have deep knowledge of systems, in general. To that end, we expect that you will take at least **six courses in the following areas. Of these six courses, you must take at least one course in each of Operating Systems, Networking, and Compilers**, unless, for some reason, appropriate courses are not offered. Courses that satisfy the breadth requirement are listed below.

- Architecture: EECS 361, 452, 453
- **Compilers: EECS 322 (required)**
- Databases: EECS 339
- Distributed Systems: EECS 345, 455

- Languages: EECS 321
- **Networking: EECS 340, 440 (1 required)**
- **Operating Systems: EECS 343, 441, 443, 446 (1 required)**
- Parallel Systems: EECS 358, 368, 468
- Performance Analysis: EECS 410, 442, 486
- Security: EECS 350, 354, 450
- Sensor Networks: EECS 369

You need not have taken these specific courses, but you should be familiar with their concepts and content. There are often additional EECS courses that may be appropriate for systems. Please consult online syllabi for these courses. With advisor approval, alternate graduate courses may be used to satisfy this requirement. Additionally, EECS 499 courses may be used with advisor approval.

Breadth Course Substitution: A student may already have satisfactory background in some area of general computer science or in computer systems, either through general knowledge or similar courses at another university. With advisor consent, one may substitute other courses. If the student feels they have satisfied any of these areas, they are encouraged to approach the relevant course coordinator for an assessment, or their advisor if the coordinator is unable to provide an assessment.

Depth in Systems: How to acquire depth in your area will be determined by your advisor. Generally, it takes the form of taking additional graduate-level courses and doing guided research and reading.

Qualifying Exam

The purpose of the Systems Qualifying Exam is to determine whether you have the essential prerequisites of being a doctoral-level researcher, namely:

Have you acquired a breadth of knowledge in computer science and computer systems? Do you have a depth of knowledge in your research area?

Can you do research?

Can you present your research well, both in written form and orally? Can you defend your research?

Can you think and discuss research extemporaneously? In other words, can you think on your feet?

If you do not meet these prerequisites, you will not pass the exam. In some cases, such as if you fail due to insufficient breadth or depth, you may be able to retake the exam. The exam can be retaken only once.

You should ask your advisor if you are prepared to take the systems Qualifying Exam. If he or she agrees, you should form a committee consisting of your advisor and at least two other Systems faculty members. Non-Systems faculty are also appropriate in some situations: you should ask your advisor. It is your responsibility to schedule the exam and reserve a conference room for it. Exams have no set

length, but past exams have taken from 2 to 6 hours. Exams are private: only your committee and you are in the room.

The Qualifying Exam begins with your presentation of a significant piece of research that you have done. One week before the exam, you must supply the committee with a paper about the work. A conference or workshop talk/paper is ideal. The committee will ask you tough questions about the content of the presentation and the work. The purpose of this part of the exam is to determine whether you are capable of doing research, presenting it, and defending it well.

In the next stage of the Qualifying Exam, each of your committee members will have the opportunity to ask you questions. Any technical question related to computer science is fair; however the focus will be on systems. Many faculty members prefer to start with a question designed to test your breadth or depth of knowledge in computer science. The committee may follow up on such questions, probing to find out what you know and what you don't know. The committee is particularly interested in how you respond to questions in areas you don't know or that you don't know the answer to. This is a common situation in doing research and the committee wants to know how you respond to it. It is appropriate and encouraged to ask questions of the committee. The committee also wants to see how you respond in an intellectual dialog.

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a “pass” is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School's deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

The thesis is judged by a committee that is chosen by the student in consultation with the student's advisor. The committee commits to reading and commenting on the thesis proposal, attending the thesis proposal defense, providing guidance and advice as the thesis work progresses, reading and commenting on the dissertation, and attending the thesis defense.

The committee must consist of at least three faculty members in the EECS Department that are also faculty in The Graduate School and at least one external committee member. This requirement is specific to Systems in Computer Science and supersedes the minimum committee required by The Graduate School.

The committee must include the student's advisor, who is generally the chair of the committee. In most cases, the faculty member should be drawn from the Systems Group, although exceptions can be made. **The external committee member should be from outside Northwestern and should hold a PhD**

Exceptions can be made in consultation with the student's advisor, but a member external to the EECS Department is required.

It is the responsibility of the student to form the committee and to schedule it for the proposal and dissertation defenses.

Thesis Prospectus

The thesis prospectus is a document written by the student that describes the proposed thesis. The proposal is generally 10-15 pages long and prepared in consultation with the advisor. It must contain:

- Thesis statement. What is the specific research problem being addressed and what is the proposed solution?
- Related work. What have other people done in this area and why is the proposed solution new?
- Prior work. What work has the student done already that suggests that he is capable of addressing the problem?
- Work plan. What the student proposes to do. Of course, research often takes one in unplanned directions. The point of the work plan (and schedule) is to describe what path is currently expected.
- Expected contributions. What artifacts and results are expected?
- Schedule. When will the major elements of the work plan be completed? Notice that writing the dissertation is an important task.

The document must be given to the members of the committee **at least one week** before the proposal defense. It is not necessary to make the proposal available online.

The proposal defense is an open, advertised, public talk, given in front of the committee and any members of the EECS Department who care to attend. The open segment of the proposal defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all his/her committee members are there physically or via phone conference. The student must assure that the proposal defense is advertised to the EECS Department at least one week before it occurs. It will specifically be posted as a thesis proposal talk.

The talk is a summary of the thesis proposal and a defense of its ideas. It's the final sanity check before the thesis work begins and is very important.

Generally, a proposal talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions or raise other private concerns.

The student will then leave the room, and the committee will determine whether the student has passed or failed the proposal defense. The student will be informed whether they passed or failed on the day of the proposal defense.

If the student passes the thesis proposal defense, we will immediately inform The Graduate School that the student's "thesis prospectus has been approved."

Thesis and Defense

The dissertation document must be complete, in draft form, before the dissertation defense can take place. It must be provided to the members of the committee at least one week before the defense is to take place. Generally, the student will have his advisor read and comment on the draft well before then.

The procedures for the dissertation defense are similar to those of the proposal defense. The defense is an open, advertised, public talk, given in front of the committee and any members of the EECS Department who care to attend. The open segment of the defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all the committee members are there physically or via phone/video. The student must assure that the defense is advertised to the EECS Department at least one week before it occurs. It will specifically be posted as a thesis defense talk.

The defense talk is a summary of the thesis work and a defense of its ideas and results. Generally, a defense talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished, further questions will be solicited from the audience. After public questions have been exhausted, the audience will leave and the committee may ask further private questions or raise other private concerns.

The student will then leave the room, and the committee will determine whether the student has passed or failed the dissertation defense. In either case, the chair of the committee will inform the student describing the results of the committee's deliberation and what additional work, if any, is to be done.

If the student passes the thesis defense, we will report this to The Graduate School. At this point, the student needs only to deliver the final version of his/her dissertation in order to graduate.

Publishing a Technical Report of the Thesis

After a successful defense, the committee will, within 2 weeks, send comments on the dissertation draft to the student. The student will then complete any additional work and make the necessary changes to the dissertation. The student must deliver the final dissertation in two ways. First, he/she must turn it in to the library. Second, **the student is expected to publish the thesis as an EECS Department technical report**. The purpose of publishing the dissertation as a technical report is to make the thesis widely available to the public.

Additional Expectations and Requirements

Systems research necessarily involves computers and networks, often many of them. This research infrastructure does not manage or configure itself, nor does the systems support group support all aspects of research computing. Systems students are expected to help in configuring, updating, and maintaining the infrastructure for the Systems Group's overall benefit.

Good systems researchers build systems; they don't just talk about or simulate them. You must know at least one low-level systems programming language such as C or C++. You must know at least one high-level application programming language such as Java, Perl, Python, Scheme, Lisp, ML, or Matlab.

If you haven't written a 1000+ line program in the language, you don't know it. If you haven't programmed on a multi-person project, you haven't programmed. You should look at the websites of the various labs that comprise the Systems Group to get a sense of the level of programming you should be able to implement.

By the end of your second year, we expect that you will have made significant research contributions that will also serve as a guide for the remainder of your time in the program.

4.5 Computing, Algorithms & Applications (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see Section 3 of this document. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in Section 3.1 of this document.

Research Area Description

The research of the Computing, Algorithms & Applications (CAA) Group focuses on theory, discrete and continuous algorithms, and software implementations and applications. Current areas of application include bioinformatics, economic models, machine learning, auctions, social networks, energy, formal methods, networking, security, self-assembly, and VLSI CAD.

Affiliated Faculty

Anindya De, Jason Hartline, Ming-Yang Kao, Konstantin Makarychev, Aravindan Vijayaraghavan,

Course Requirements

Each student in the CAA Group must take at least 3 courses from the following list:

- EECS 479 Nonlinear Optimization
- EECS 457 Advanced Algorithms
- EECS 496 Computational Complexity

EECS 479 can be substituted by IEMS 450-II

The CAA Group stipulates that at most 3 courses can be EECS 499 or EECS 510.

Beyond the above stipulations, there is no required list of courses, but your advisor will ensure that you have a good understanding of not only your own research area, but also of related fields. Ideally, you should take at least one course from Computer Engineering and Systems (CES) and at least one course from another research group in the EECS Department. However, in some cases, it may be more appropriate to satisfy the breadth requirement by taking courses in other departments.

Qualifying Exam

The purpose of the CAA Group Qualifying Exam is to determine whether you have the essential prerequisites for being a doctoral-level researcher, namely:

- Have you acquired sufficient breadth of knowledge in computing and algorithms?
- Do you have a depth of knowledge in your research area?
- Can you present your research (or survey a research topic) well, both in written and oral form?

The Qualifying Exam Committee consists of your advisor and at least two other EECS Department faculty (who can be substituted by faculty from other departments at Northwestern with the consent of

your advisor and the CAA Group's head). The Qualifying Exam will typically take two hours and is private: only your committee and you are in the room.

You have two options for the Qualifying Exam: (a) you can present the results of research you have done (a conference or journal paper is ideal); or (b) you can present an in-depth survey of a research topic assigned to you by your advisor. Fourteen days before the exam, you must supply the committee with a document about the work you will present.

The exam will begin with your presentation. The committee will ask you questions about the content of the presentation and the work. In the next stage of the exam, each of your committee members will have the opportunity to ask you technical questions related to your research area or the core courses you have taken.

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a "pass" is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School's deadline..

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

The prospectus must be approved by a faculty committee. A minimum of three individuals must serve on the prospectus committee. Upon formation of the prospectus committee, the student should submit the PhD Prospectus form through The Graduate School forms.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it.

The prospectus defense is an open public talk, given in front of the PhD thesis committee and any members of the Northwestern community who care to attend. The talk should last approximately 50 minutes. The student will be informed whether he/she has passed or failed on the day of the proposal defense. In either case, the chair of the committee will write a formal letter to the student describing the results and what additional work, if any, is to be done.

Thesis and Defense

The thesis document should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The procedures for the PhD thesis defense are similar to those of the proposal defense. The defense is an open public talk, given in front of the committee and any members of the EECS Department who care to attend. The talk is a summary of the PhD thesis work and a defense of its ideas and results.

After a successful thesis defense, your committee will, within 7 days, send comments on the thesis draft to you. You will then complete any additional work and make the necessary changes to the thesis. You must deliver the finalized thesis to The Graduate School.

Additional Expectations and Requirements

You are expected to finish your PhD study in 4 - 5 years. Generally, you should make every effort to follow the following schedule:

1. Find a faculty member to be your PhD advisor no later than Spring Quarter of the 1st year;
2. Take the Qualifying Exam by Spring Quarter of the 2nd year, and no later than the end of your 3rd year;
3. Take the PhD thesis proposal defense by Spring Quarter of the 3rd year.

In choosing an advisor, you should take the initiative to discuss with any faculty member who interests you upon your joining Northwestern University or even before then. You should engage in research as soon as possible, but the timing will depend on your academic background and should be decided in consultation with your advisor. In your first year or two, you will also be taking classes, but doing research will determine your success as a graduate student.

By the end of your 2nd year, you will take the CAA Group qualifying exam, which is described in detail below. The next step after the qualifying exam is to find a PhD thesis topic. A thesis proposal is presented after you have done substantial work, and the potential research contributions can be envisioned and defended. The final step is to write and defend a PhD thesis.

Students are encouraged to seek out summer funding of their own in the form of internships at quality research laboratories, if this is deemed to enrich their learning experience.

4.6 Cognitive Systems (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see Section 3 of this document. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in Section 3.1 of this document.

Research Area Description

Work in this area focuses on: Understanding how minds work, from a computational perspective; Creating systems for helping people learn better and perform better, using principles of Cognitive Science; Using Artificial Intelligence (AI) techniques to create new forms of interactive entertainment.

Affiliated Faculty

Brenna Argall, Larry Birnbaum, Douglas Downey, Ken Forbus, Darren Gergle, Kristian Hammond, Larry Henschen, Michael Horn, Ian Horswill, Bryan Pardo, Christopher Riesbeck, Uri Wilensky; and Haoqi Zhang

Course Requirements

There are no specific coursework requirements beyond those specified by the EECS department and The Graduate School.

Coursework will vary depending on exact interests and background of each student. Someone deeply interested in cognitive science might take a number of courses in psychology. Someone interested in creating new kinds of educational software might take some of their courses in the School of Education and Social Policy. Someone interested in more applied AI might take some of their courses in human-computer interaction and interface design.

While the following courses are not required, each student should be conversant with the material in these courses, as their content is assumed knowledge in the Cognitive Systems Qualifying exam.

- EECS 325 Artificial Intelligence Programming
- EECS 337 Introduction to Semantic Information Processing
- EECS 338 Practicum in Intelligent Information Systems
- EECS 344 Design of Computer Problem Solvers
- EECS 348 Introduction to Artificial Intelligence
- EECS 349 Machine Learning
- EECS 371 Knowledge Representation

Qualifying Exam

The Cognitive Systems Qualifying Exam is a one-day written exam, traditionally the Monday or Tuesday after Finals week of Spring Quarter. The exam is open-book, open-notes, and graded anonymously. Graduate students must take the exam at the end of their second year.

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a “pass” is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School’s deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

All graduate students will write a thesis proposal before undertaking serious work on their PhD research. The written proposal must be approved by a CogSys Group-approved thesis committee. After approval, the student must give a public presentation of the thesis proposal.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it. The oral component consists of a formal presentation of the proposed research to the thesis committee, as one might give at a departmental colloquium. You should plan the presentation for 45 minutes, with another 15 - 45 minutes for questions.

Thesis and Defense

The required format of the final thesis is governed by The Graduate School. Please consult their website for details.

The thesis document should be submitted to the committee at least **two weeks before the thesis defense** to allow time to read and critique it.

Two presentations are required. The actual defense of the thesis is an oral presentation, open only to faculty and other members of the University with PhD degrees. A public presentation of the thesis is required after the defense is passed.

Additional Expectations and Requirements

It is crucial to realize that, unlike undergraduate study, graduate school is primarily about research, not courses. We expect you to do well in your courses, naturally. However, we expect you to become involved in research starting in your first year. Independent-study projects are a good way to explore what kind of work you want to become involved in or just to wrap your head around something different if you are already involved in a project. Instead of a master's thesis, we encourage students to publish research in conferences and journals, starting early in their career

4.7 Graphics & Interactive Media (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see Section 3 of this document. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in Section 3.1 of this document.

Research Area Description

Graphics & Interactive Media (GIM) is a Program of Study for students interested in human-computer-interaction, multimedia, graphics, audio processing, human computation and social computing.

Affiliated Faculty

Larry Birnbaum, Oliver Cossairt, Darren Gergle, Kristian Hammond, Michael Horn, Ian Horswill, Bryan Pardo, Jack Tumblin, Uri Wilensky, and Haogi Zhang

Course Requirements

There are no specific required courses for GIM students. However, all GIM students are required to demonstrate proficiency in the subfields listed below.

- Fundamentals of Programming: EECS 111+ EECS 211+ EECS 214
- Theoretical Computer Science (1 course): EECS 335, EECS 336
- Systems (2 courses drawn from any of the following categories)
 - Operating systems: EECS 343
 - Computer architecture: EECS 361
 - Networking: EECS 340
 - Programming languages: EECS 321, EECS 322
- Graphics or media (1 course from any of the following categories)
 - Audio, visual or multimedia processing: EECS 351, EECS 352
 - Computer games: EECS 370, EECS 396
- Cognitive and social systems (1 course from any of the following categories)
 - Artificial Intelligence: EECS 348, EECS 349, EECS 371, EECS 474

- Cognitive science: An advisor-approved cognitive science course
- Social science: An advisor-approved social science course
- Learning sciences: EECS 313

Proficiency means showing knowledge comparable to getting an A in an undergraduate course on the topic at a peer institution. For programming knowledge, proficiency may, at the discretion of the advisor and director of graduate studies, be demonstrated through significant work experience in the software industry. Students entering the doctoral program with an undergraduate degree in computer science will likely satisfy most or all of the requirements through coursework on their undergraduate transcript.

Any requirements not satisfied through prior coursework should be resolved by taking the appropriate course at Northwestern University. Students should discuss with their advisors to identify appropriate courses to take. Course numbers shown are courses offered at Northwestern University that would satisfy the requirement, but other courses may also apply.

It is the responsibility of the student to make a case for how each course taken at a prior institution satisfies a requirement. This may include providing their transcript, the syllabus of each class in question. This case should be made to the student's academic advisor. If there is any question about the applicability of a course after discussion with the advisor, the case should be brought to the Co-Director of Graduate Studies for Computer Science.

Students entering with an undergraduate degree in computer science should complete this work in their first year, those with undergraduate degrees in other areas should complete this within two years.

Qualifying Exam

The qualifying exam consists of presenting the results of a small-to-medium-sized, completed research project to an examination committee of three members of the graduate faculty, at least two of which should have a primary, secondary or courtesy appointment in Computer Science. Although the project may be a component of a larger group project, the work reported on should be solely by the student, not joint work with other students.

What the exam consists of:

The exam has two parts: the written component and the oral component.

The written component consists of a mock (or real) conference paper on the project. Although the project need not be published work, the student should identify a conference in which the project could plausibly be published and write the paper to be consistent with the submission requirements (length, etc.) for that conference. The paper submitted to the committee should be a final version, approved by the student's advisor. In certain cases, a committee may agree to accept a dissertation proposal in lieu of a completed project paper. The paper should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The oral component consists of a formal presentation of the project, as one might give at a departmental colloquium. It should be roughly 45 minutes in length, with another 15 - 45 minutes for questions. The

purpose of the oral exam is to probe the student's analytical and research skills, although the committee may ask whatever questions it feels are appropriate.

When to take the exam: The expectation is that the qualifying exam will be completed prior to the start of the student's third year in the program. In exceptional cases, this may happen later, subject to the deadlines specified by Northwestern's Graduate School on how late in the degree the exam may be taken without being placed on academic probation or being excluded from the graduate program.

Outcomes:

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a "pass" is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School's deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

The written component of the thesis prospectus specifies:

- The topic to address
- Why it's important
- The relevant work that has been done before on the topic
- How the student expects to improve upon existing relevant work
- A schedule for the work to be done. This is intended as a planning tool for you to help ensure plans are practical.

A typical prospectus length in GIM is roughly 15 to 20 pages.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it. The oral component consists of a formal presentation of the proposed research to the thesis committee, as one might give at a departmental colloquium. You should plan the presentation for 45 minutes, with another 15 - 45 minutes for questions.

Thesis and Defense

The thesis document should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The procedures for the PhD thesis defense presentation are similar to those of the proposal defense. The defense is an open public talk, given in front of the committee and any members of the EECS Department who choose to attend. The talk is a summary of the PhD thesis work and a defense of its ideas and results.

After a successful thesis defense, your committee will send comments on the thesis draft to you. You will then complete any additional work and make the necessary changes to the thesis. You must deliver the finalized thesis to The Graduate School.

Additional Expectations and Requirements

None.

5 Student Organizations

Institute of Electrical and Electronics Engineers (IEEE) Faculty Counselor: Prof. Alan Sahakian

The Institute of Electrical and Electronics Engineers (IEEE) is the principal professional society in the electrical engineering profession. It has over 300,000 members, including 38,000 student members. It publishes more than 40 technical journals and sponsors or co-sponsors more than 1,000 scientific conferences and

meetings around the world covering all aspects of electrical engineering and related fields. It has a student branch in every major university in the free world that offers an electrical engineering curriculum.

The IEEE Student Branch at Northwestern University is well established and sponsors a number of technical meetings every year. Student members are entitled to receive the IEEE's monthly publication, *Spectrum*; subscribe to the special publications of the IEEE technical societies (there are 35); and attend any of the IEEE-sponsored or co-sponsored conferences at substantially reduced rates. Students are encouraged to join the organization. Application forms can be obtained at the EECS Department Office or from Prof. Sahakian. (Current basic dues are \$30/year.)

Optical Society of America (OSA) Faculty Adviser: Prof. Prem Kumar

The Optical Society of America was founded in 1916 with the mission to increase and diffuse the knowledge of optics and to promote the common interests of and encourage cooperation among scientists, designers, and users of optical apparatus of all kinds. Today there are over 12,500 members worldwide representing 50 countries. Through its sponsorship of conferences, peer-reviewed journals and a monthly optics and photonics news magazine, OSA has emerged as one of the leading and most

prestigious organizations serving the optics and photonics community.

Northwestern is very active in the OSA with four professors (Ho, Kumar, Razeghi, and Wessels) who are Fellows of the society. The Student Chapter hosts regular meetings with invited speakers, participates in community outreach activities, and sponsors social gatherings for its members. Students are encouraged to join the Student Chapter to become involved with the exciting research activities of the optics and photonics community at Northwestern University.

Beta Tau Chapter of Eta Kappa Nu Faculty Adviser: Prof. Allen Taflove

Eta Kappa Nu is the international electrical and computer engineering honor society, now affiliated with the IEEE. It was founded in 1904 at the University of Illinois and now includes more than one-hundred collegiate and alumnus chapters. Our chapter at Northwestern, Beta Tau, was installed on January 24, 1948. Membership is by invitation-only to electrical and computer engineering students in their junior and senior years of study who show strong promise of success in their chosen field as evidenced by excellence of scholarship and character.

Tau Beta Pi

Tau Beta Pi is the national engineering honor society (for all engineering specializations). Membership is by invitation-only to students in their junior and senior year of study in the McCormick School who demonstrate excellent scholastic achievement and character.
<http://msgroups.tech.northwestern.edu/tbp/>

Northwestern University Amateur Radio Society (NUARS) Faculty Advisers: Profs. Alan Sahakian and Allen Taflove

The Northwestern University Amateur Radio Society (NUARS) was founded in 1949. NUARS provides members of the Northwestern University community who hold amateur radio ("ham") licenses issued by the U.S. Federal Communications Commission (FCC) the opportunity to operate its FCC-licensed amateur radio club station, W9BGX, while at school.

Running the legal power limit (1,500 watts) on the HF amateur bands into very capable antennas atop the north and south towers of Tech, W9BGX has one of the most powerful amateur signals in the U.S. Depending upon ionospheric conditions, this allows operators of W9BGX to contact hams in distant lands all around the globe (“DX”) without the need for any infrastructure. This can be crucial in times of emergencies when such infrastructure could fail.

In addition to working DX, chasing ham awards, and handling messages, members of NUARS can experiment with circuits and antennas, as well as emerging digital communications modes. Membership is open to all Northwestern students, faculty, and staff, although only FCC-licensed members may operate the transmitting equipment. Electrical engineering students with an interest in communications and experimentation are especially encouraged to join.

Women in Computing (WiC)

The mission of WiC is to engage in activities and projects that aim to improve the working and learning environments for women in EECS at Northwestern. This includes promoting activities that result in more equal representation of women in EECS such as mentoring, serving as a repository of information about programs, documents and policies of concern to women in EECS, and organizing events that benefit the EECS community as a whole. For more information and to get involved, email the executive board at wic@u.northwestern.edu and subscribe to the mailing list women-eecs@listserv.it.northwestern.edu

Graduate Electrical Engineering and Computer Science Society (GEECS) Faculty Adviser: Prof. Alan Sahakian

GEECS is a graduate student-run organization founded in January 1997. The goal of GEECS is to help foster a sense of community and to provide a venue for social interaction between graduate students and faculty members of the many groups within our department.

Association for Computing Machinery (ACM) Faculty Adviser: Prof. Ian Horswill

The ACM (acm.org), founded in 1947, is the oldest society for computer science. It publishes over 40 journals as well as the proceedings of innumerable conferences and workshops. ACM provides steep discounts for student members, allowing them ready access to the state of the art in the field, both in research and practice, through print and the award-winning ACM Digital Library. The Northwestern ACM student chapter (acm.cs.northwestern.edu) was founded in 1996. It provides technical learning opportunities, social activities, and long-term projects. It also has a range of equipment and services available for use in student projects. All of its activities are open to all Northwestern students.

<http://acm.cs.northwestern.edu/>

Systems Reading Group

The Systems Reading Group is an informal group that meets to read and discuss two to three systems research papers every week.

We construe “systems” fairly broadly. Anyone involved with Northwestern’s computer science and computer engineering areas are welcome to attend.

We generally talk for 1-1.5 hours, but people are welcome to come and go as they please. The general protocol is that we round-robin among the people in the group to choose the “paper dictator” of the week. The paper dictator chooses the papers for the week, tells everyone where to find them, and is responsible for leading the discussion of the papers when we meet.

No formal presentation of the paper is required. Faculty and systems graduate students can recommend papers if you're not comfortable picking them yourself. Every week, each member of the group should send a short (a paragraph at most) comment/summary of each paper to the mailing list, [systems-reading-group- list@cs.northwestern.edu](mailto:systems-reading-group-list@cs.northwestern.edu).

Society of Women Engineers (SWE)

The Society of Women Engineers is a national organization dedicated to promoting interest and encouraging women to pursue the fields of science and engineering. SWE gives support, guidance and recognition to women engineers and other engineering students. Today, SWE is a nationally recognized professional, educational, non-profit, service organization. Its student section membership includes graduate and undergraduate female and male engineers. The Northwestern SWE chapter was founded in 1976.

The Society of Women Engineers encourages women in engineering and science fields. We work to increase awareness of the opportunities for women in engineering, to help overcome challenges that are encountered, and to increase communication, teamwork and leadership. SWE provides an environment of personal and professional growth to compliment the academic experience. Along with responsibilities come the rewards of accomplishing goals, making a difference in the lives of others, affecting policy at the university and building a network of professional friends. The SWE experience prepares its members to be successful professionals. SWE has many activities to help you develop the skills to succeed.

<http://msgroups.tech.northwestern.edu/swe/>

National Society of Black Engineers (NSBE)

The National Society of Black Engineers is a 501(C) (3) non-profit association that is owned and managed by its members. The organization is dedicated to the academic and professional

success of African-American engineering students and professionals. NSBE offers its members leadership training, professional development, mentoring opportunities, career placement services and more!

NSBE is comprised of more than 300 collegiate, 75 professional and 75 pre-college chapters nationwide and overseas. NSBE is governed by an executive board of college students and engineering professionals and is operated by a professional staff in our World Headquarters located in Alexandria, VA. NSBE with its unique characteristics has accomplished more for Black engineering students than any other organization in the world. The same light that NSBE spreads to students and professionals in the United States is also relevant in African, European, South American, Asian, Caribbean, Canadian, Australian, and Pacific Islander countries for people of color. It is the NSBE leadership's vision that the organization will replicate itself in countries around the world, creating a world network of Black engineers, scientists, and technologists through its international operations. <http://www.nsbe.org/>

GRS - The Graduate Research Seminar in Computer Science and Engineering Faculty Adviser: Prof. Peter Dinda

The Graduate Thesis Seminar is a place where graduate students in Northwestern's EECS Department can talk about their work and learn how to give good presentations through gentle feedback from faculty and fellow students. Talking about your work can provide a useful forcing function to advance research and giving good talks is a critical skill for computer scientists and engineers. There is also free lunch! Undergraduates are welcome. GRS meets each Wednesday during the school year at noon in Ford's ITW classroom.

<http://geecs.eecs.northwestern.edu/GRS/GRS>