Navigating the PhD Options in CMS

This document gives an overview of the typical student path through the four Ph.D. programs in the CMS department – ACM, CDS, CS, and CMS. Note that it is not a replacement for discussions with your faculty advisor or for the information in the Caltech Catalog, which lists the official degree requirements. Rather, this document is meant to outline the typical progression students make through the degree.

Overview of the requirements

The requirements basically fall into three categories: coursework, exams, and research. In each option, the coursework consists of a set of core courses taken during the first year, followed by a set of elective courses meant to encourage breadth & and depth of knowledge. Beyond the coursework, students have three exams: a *preliminary exam* during the first year, a *candidacy exam* during the 2nd or 3rd year, and a *thesis defense*. Additionally, all students are expected to attend the departmental seminars regularly (and are required to do so in the first year of their studies).

The typical progression through the program is outlined in the following. Note that at the end of each year, students receive "progress letters" from the option representative faculty evaluating their progress toward the PhD so far and outlining hurdles for the coming year. More detail about these progress letters is included below.

What to expect during year 1

The goal for the first year of the program is to ensure that students get started on research and build a basic core knowledge through coursework. So, during the first year, students focus on two things: (1) finding a research adviser and starting research, (2) completing the "core" and passing the preliminary exam.

Finding an advisor

Most students have an idea of 1-2+ possible research advisors before arriving at Caltech. Thus, the task for the first year is to attend the group meetings of these multiple possible advisors, talk to their students, take topics courses in related areas, and (of course) meet with them and discuss possible research projects, etc.

In many cases, students find a strong match with an advisor during the first or second term, so that they can and have already begun working on an initial project by the time the third term begins. All students should identify an advisor no later than the end of the third term. It is also common for students to work with multiple faculty members throughout the first year, and even beyond.

During the first year you should try to:

- Work hard to develop rigorous foundations via your first-year courses
- Attend many seminars (especially the CMS Keller Colloquium and the IST Lunch Bunch)
- Attend group meetings for multiple faculty members
- Do lots of reading (papers and books)
- Start to work on one or two very specific open research questions to get your hands dirty

Note that the most important goal is to build your foundational knowledge through courses and the prelims. You will need to learn a lot and learn it thoroughly. But, we hope that you don't get lost in the coursework -- remember it is a tool for research and so try to find time to read papers and attend talks too!

You should also make sure to spend time getting to know many of the CMS faculty & and students (not just your advisor and lab mates). Do not underestimate the importance of building your social cohort with students inside CMS and outside CMS.

The core classes and prelim exam

The core classes and prelim exam requirements differ slightly across options, though they all have significant overlap. We go through them in detail here.

ACM option

The core ACM classes include the list below, plus an application elective course. The application elective course in the first year is selected, with the recommendation of the student's adviser, from among a wide range of courses offered by an outside option within the Institute.

Core classes are offered in the 1st and 2nd quarter. Students should select a subset of these to take during their first year in consultation with their advisor. A standard load is 3 or 4 course per term.

Fall core classes

- ACM 101a. Methods of Applied Mathematics
- ACM 106a. Introductory Methods of Computational Mathematics
- CMS/ACM 107. Linear Analysis with Applications
- CMS/ACM 113. Mathematical Optimization
- CMS/ACM 117. Probability and Random Processes
- MA 108a. Classical Analysis

Winter core classes

- ACM 101b. Methods of Applied Mathematics
- ACM 105. Applied Real and Functional Analysis
- ACM 106b. Introductory Methods of Computational Mathematics
- MA 108b. Classical Analysis

Spring core classes

- MA 108c. Classical Analysis

Prelim exam: The preliminary exam consists of 3 written exams, each of 3 hours duration administered at the beginning of the third quarter. All first-year students will be contacted during the second term about scheduling the exam. The purpose of the exam is to evaluate expertise in the topics included in the fall and winter core courses listed above. To this end the student, in collaboration with their academic advisor, selects 3 subject areas to be examined in. These are taken from the following list: ACM101a, ACM101b, ACM105, ACM106a, ACM106b, ACM107, ACM113, and ACM117.

CDS option

The core classes include four courses during the fall term, one during the winter term and one during the spring term. Students are expected to take these during their first year (note that CMS/ACM 117 or CMS/ACM 113 can also be taken during Fall term). The fall term is focused on mathematical fundamentals, the winter is focused on dynamics and the spring is focused on nonlinear control. Additional courses are recommended depending on interests, e.g., CMS 139, 144, and 155 in the Winter, and research and topics courses (e.g., CDS 141, 242 or 244) in the Spring.

Fall core classes:

- CDS 131: Linear Systems Theory
- CMS/ACM 107. Linear Analysis with Applications
- CMS/ACM 113. Mathematical Optimization
- CMS/ACM 117. Probability and Random Processes

Winter core classes

- CDS 231: Robust Control Theory
- CDS 232. Nonlinear Dynamics

Spring core classes

- CDS 233. Nonlinear Control

Prelim exam: The exam will take place during the third term in residence, and all first-year students will be contacted during the second term about scheduling the exam. The purpose of the exam is to evaluate expertise in the topics included in the core courses listed above. The exam consists of modules related to each of the core courses taken in the first two quarters of study. Students will be examined on the two core CDS courses, CDS 131 and CDS 232, along with concepts from CMS 107 or CMS 113.

Two and a half hours are allotted to the exam. During the first 90 minutes, students will be given a written copy of the exam questions, and will have the opportunity to prepare answers; during the final 60 minutes, students will answer the questions orally at the direction of the committee. While preparing answers, students are not allowed to consult references of any kind. All

information that students are not expected to know (or be able to derive) will be supplied as part of the question.

CMS option

The core classes include three courses during the fall and winter terms. The fall term is focused on mathematical fundamentals and the winter is focused on computing fundamentals. The spring term is then open for research and topics courses.

Fall core classes: Mathematical Fundamentals

- CMS/ACM 107. Linear Analysis with Applications
- CMS/ACM 113. Mathematical Optimization
- CMS/ACM 117. Probability and Random Processes

Winter core classes: Computing Fundamentals

- CMS/CS 139. Analysis and Design of Algorithms
- CMS/CS/EE 144. Networks: Structure & Economics
- CMS/CS 155. Machine Learning & Data Mining

Students often come in with widely varying backgrounds. It is not required or expected that students complete all six courses during their first year. It is required that students complete at least two courses per term in order to prepare for the preliminary exam. Minor modifications to the core requirements (e.g., swapping one course for one of the CDS core courses) is possible subject to the approval of the option rep.

Prelim exam: The exam will take place during the third term in residence, and all first-year students will be contacted during the second term about scheduling the exam. The purpose of the exam is to evaluate expertise in the topics included in the core courses listed above. The exam consists of modules related to each of the six core classes. Students are to choose 3 courses to be examined on (including at least one from each of the fall and winter terms). This choice is made *before* seeing the exam.

Three hours are allotted to the exam. During the first two hours, the student is given a written copy of the exam questions, and has the opportunity to prepare answers; during the final 60 minutes the student answers the questions orally at the direction of the committee. While preparing your answers, students are not allowed to consult references of any kind. All information that students are not expected to know (or be able to derive) will be supplied as part of the question.

CS option

The CS option does not require any specific core courses. Instead, students are encouraged to craft their own curriculum in consultation with their advisor. Students are required to take 54 units (~9 courses), and students are encouraged to take 2-3 courses during each of their first

two terms in order to prepare for the preliminary exam topics, each of which has an associated core course offered during the fall or winter term.

Prelim exam: The exam will take place during the third term in residence, and all first-year students will be contacted during the second term about scheduling the exam. The purpose of the exam is to evaluate expertise in the topics of Algorithms & Complexity, Networking & Systems, Machine Learning, & Mathematical Foundations. The exam consists of three modules related to these areas. The modules are to be chosen by the student, according to the following scheme. First, the student should choose one module that pertains to the Mathematical Foundations area, chosen among: Optimization (ACM 113), Linear Algebra (ACM 107), or Probability & Stochastics (ACM 117). Second, the student should choose two modules among the tree possibilities of Algorithms & Complexity (CMS 139), Networking & Systems (CS 143), Machine Learning (CMS 155). This choice is made *before* seeing the exam. Course numbers are meant to be representative of the material covered by the exam, but it is not required to have taken the course in order to select the associated module.

Three hours are allotted to the exam. During the first 2 hours students will be given a written copy of the exam questions, and will have the opportunity to prepare answers; during the final 60 minutes students will answer the questions orally at the direction of the committee. While preparing answers, students are not allowed to consult references of any kind. All information students are not expected to know (or be able to derive) will be supplied as part of the question.

General guidelines on courses and prelim exam

Depending on student and adviser wishes, students may choose to defer some core courses to the second year or take additional courses beyond the core courses during their first two terms. Students without a background in the areas of the core courses may consider deferring such courses, and should consult with the option representative about this option. Note that students wishing to get started quickly on research should likely not take courses beyond the required core during the first two terms.

For additional information about the format and questions on preliminary exams, you should feel free to discuss relevant references, etc. with members of the faculty. All material covered in the syllabi of the core courses is fair game in the exam. The level of the questions tends to be at the level of an easy-to-medium homework problem. During the winter term a rubric and detailed list of topics for the preliminary exam will be given to all first year students.

We encourage you to discuss the exam with the professors of the core courses to get more information. Additionally, examples of prior preliminary exams will be made available by the option representative during the winter term and second year students will arrange practice preliminary exam sessions for first year students in order to help them prepare.

Prelim exam outcomes:

Four types of decisions are possible: *pass, conditional pass, partial retake, full retake*. A student with a *pass* or *conditional pass* has passed this hurdle of the program and is eligible to form a committee and enter candidacy. However, a student with a *conditional pass* will usually be required to satisfy some additional requirements, such as successful completion of specified coursework or TA a course to obtain further background. Students who are asked to do a full or partial retake will retake some or all of the subject exams at the beginning of the summer term. It is not unusual for students to have to retake one or more of the subjects, so students should not be discouraged if that happens. We do not view prelims as a "pruning" mechanism and we hope that everyone eventually passes their prelim exam. The format of the retake is the same as for the initial exam, except only a subset of the areas are examined. Three types of decisions are possible for the retake: *pass, conditional pass, fail*.

Budget for computing

One of the first things you'll likely want to do when you arrive is buy a desktop/laptop. For this purpose, every student is budgeted $2000 to spend however on computing related equipment, e.g., desktop, laptop, monitor, ergo keyboard, presentation clicker, etc. This $2000 can be spent anytime while at Caltech. Once it runs out, you should coordinate with your adviser regarding additional purchases. If you are unsure what computer would be most appropriate, we recommend chatting with your possible advisers as well as other students in the department. Of course, please save all receipts and submit them to either your adviser's admin or Maria Lopez.

What to expect during years 2-3

During the second and third year, students are typically beginning to pursue independent research in earnest. Students should have settled on a primary adviser before the second year, though many continue to work with multiple faculty throughout their second and third years.

Students typically finish their additional courses beyond the core requirements during their second year, and these should certainly be finished before the end of the third year. These are described below. The largest hurdle for during this period is the candidacy exam, which is required to be completed by the end of the third year.

Additional course requirements

ACM option

In the second and third years, students are expected to take 7 additional graduate-level courses appropriate to their chosen research area beyond the core requirements. These would normally include graduate-level ACM or CMS courses such as CMS/ACM 201 ab, 210 ab, 216, 217, CDS 140, etc., as deemed appropriate to the student's research program, and which must be selected in consultation with the student's research adviser.

CDS option

The courses taken during the 2nd and 3rd years are meant to provide both depth into their proposed research area and breadth across CDS related areas. Both of these requirements are extremely flexible. Students must complete 3 depth courses in ACM/CDS/CMS; examples of which include CMS 119, CMS 144 and CMS 155 along with advanced CDS courses including CDS 241, CDS 242, CDS 243 and CDS 244. Additionally, students must complete 3 breadth courses not in ACM/CDS; for example, the three course sequence in robotics and Autonomy (ME 133ab and CMS/EE/ME 135) or the course sequence in flight control (Ae 103abc). The plan for the 3 depth courses and 3 breadth courses should be discussed and approved by the student's adviser.

CMS option

The courses taken during the 2nd and 3rd years are meant to provide both depth into their proposed research area and breadth across CMS related areas. Both of these requirements are extremely flexible. For the *breadth* in requirement students must complete 27 units of 100+ level courses in Engineering, Science, Mathematics, or Economics. These can really be almost anything and are meant to provide expertise in topics beyond the core research focus. For the *depth* requirement students must complete 27 units of courses within one particular subject area. The plan for these 27 units should be discussed and approved by the student's adviser.

CS option

The courses taken during the 2nd and 3rd years are meant to provide both depth into their proposed research area and breadth across CMS related areas. Depth is provided by the completion of the 54 units of CS graduate level courses, and Breadth is provided by 27 units of courses outside of computer science. The plan for these 27 units should be discussed and approved by the student's adviser.

Candidacy Exam

All students must pass a candidacy oral examination, which will be administered by a committee that consists of four faculty, is approved by the option representative. The committee may not be chaired by the student's research adviser. The committee must include at least three Caltech faculty and at least two faculty from the CMS department. The examination will ascertain the student's breadth and depth of preparation for research in the chosen area.

Students are encouraged to complete the Candidacy Examination by the end of their third academic year at Caltech, though this is not always feasible. A student who fails to satisfy the requirements of the Division for candidacy by the end of the third term of the third year in residence must obtain special permission from the Division to continue in the program.

The procedures for scheduling and taking the exam are as follows.

1. Select a tentative date (determined by the candidate and his or her research adviser) and an examining committee of at least four members. Check with the department option administrator to avoid time/place conflicts. Then, check with members of your committee to see that the date is satisfactory. The committee must be approved by the Option Representative before the exam is scheduled.

2. Go to the Graduate Degree Progress and select the Ph.D. Candidacy Tab. Please complete your Plan of Study. If you choose to pursue a minor, please see department option administrator Maria Lopez.

3. Committee members can request additional information prior to the candidacy exam. Commonly requested information includes the student's prior research and future research plans. In some cases, the committee can request a 2-3 page research progress report -- such a report should concisely state your progress to date, your proposed research topic, and the nature of the contribution which you expect to make in the general problem area. Please confirm with you committee what requirements they have no less than one month from your candidacy date.

4. The oral examination will consist of a public 50 minute presentation followed by a closed-door examination of the candidate by the committee. The presentation should include an overview of the general research area, a description of (at least) one piece of original research, and a proposed research direction.

5. Once the Candidacy Examination is completed satisfactorily, the members of the examining committee will approve in the Graduate Degree Progress system. You will be notified later by the Dean of Graduate Studies that you have been admitted to Candidacy for the Degree of Doctor of Philosophy.

What to expect during years 4-6

Following the candidacy examination, students focus on their Ph.D. dissertation research. Typically students graduate in five years, though some take less/more time.

During this period, each student will form a thesis committee (possibly the same as the candidacy committee) consisting of at least four faculty approved by the option representative. The committee may not be chaired by the advisor. The thesis committee will meet as needed, but at least yearly, in order to advise the student.

1. Office for proofreading; this can be done by Caltech dropbox or email. This should be dThe final hurdle is, of course, the Ph.D. defense. A final oral examination will be scheduled and given after the PhD thesis has been submitted for review to the student's adviser and thesis committee. The thesis examination is a defense of the thesis research and a test of the candidate's knowledge in his or her specialized fields. Normally, the

defense will consist of a 50-minute public lecture followed by an examination of the thesis by the thesis committee.

Procedures

1. At least *three weeks* prior to the exam date students need to obtain the following forms from the Graduate Office: “Petition for Exam” & “Application for Approval of Thesis”

2. The date of the Ph.D. exam and the committee members will be determined by you and your research adviser and must be approved by the Option Representative. The committee must include at least four members, at least three of which are Caltech faculty and at least two of which are faculty from the CMS department. Check with members of your committee for agreement on the date and time of the exam. Once a definite date and committee are set. Login to Graduate Degree Progress (Ph.D. Tab) and complete Examination Committee. The Graduate Degree Progress System will send a confirming memo to the committee members.

Procedures for Submitting the Ph.D. Thesis

1. *At least two weeks prior to your exam*, supply each member (four are needed, one of whom can be a qualified Ph.D. from off-campus) of your committee with a copy of your thesis. If corrections or revisions are required, it is your responsibility to:
    - make the necessary corrections or revisions;
    - submit the revised thesis to members of your examining committee; and
    - all committee members will approve via Graduate Degree Progress
    - final approval will be done by your advisor on the Graduate Degree Progress System. Once the acceptance of the corrections or revisions.

2. Submit one copy of your thesis to the Graduate Office at the same time the thesis is submitted to your committee members. You will be notified as soon as the proofreading is complete (usually 10 business days). For final thesis submission to the Caltech library go to: http://libguides.caltech.edu/c.php?g=512628&p=3502483

Progress Letters

All students will receive yearly “Progress Letters” during the summer term. These letters are an important source of feedback and advice for students (and their advisors), especially in the later years of the PhD program when the course and prelim requirements have already been satisfied.

To prepare these letters all department faculty meet and discuss each student individually -- considering progress and performance in courses and research. Then, a letter is composed to the student by the option representative to provide details feedback on their performance as well as advice for the coming year.

Before the faculty meeting (typically early in the spring term), each student is asked to submit a summary of their accomplishments during the year so that these can be brought up during the faculty discussion.

Department Colloquium

The Keller Colloquium in CMS is a seminar series that brings in well-known academic and industry speakers from across CS, ACM, EE, and CDS. *Students in the department are required to attend during their first year, and students are strongly encouraged to attend during their entire time at Caltech.*

The colloquium is run by students chosen from all the PhD options in the CMS department. For each invited speaker, a student is designated as a host to help arrange a meeting schedule for the speaker during their visit, including both student and faculty meetings. The administrative staff will help with travel and scheduling arrangements. NOTE: During COVID the seminar and visits are done in a virtual manner.

If you would like to serve as a host for invited speakers, please let your faculty adviser know.

Other Important info for getting started at Caltech

Acronyms

- ACM – Applied and Computational Mathematics
- CAST – Center for Autonomous Systems and Technologies
- CDS – Control and Dynamical Systems
- CMI – Center for Mathematics of Information
- CMS – Computing and Mathematical Sciences (it's both a department and an option)
- CMX – Computational Math + X
- CNS – Computation and Neural Systems (a related PhD option)
- DOLCIT – Decision, Optimization, and Learning at the California Institute of Technology
- IQIM – Institute for Quantum Information and Matter
- IST – Information Sciences and Technology (an umbrella initiative sponsoring many groups/centers involved in computation and mathematics)
- MPP – The Molecular Programming Project
- RSRG – Rigorous Systems Research Group (CS/EE Networking/Systems group)
- SISL – Social and information sciences laboratory (CS/Econ center)

Relevant mailing lists

Email Sydney Garstang (sydney@caltech.edu) to get added to these lists. She'll either add you or point you to the right place. You should be automatically on the appropriate building/student lists but likely need to email to get placed on the research group lists.

Building Lists:

- annenberg@cms.caltech.edu
- steele-house@cms.caltech.edu
- cds-all@cds.caltech.edu (We don't have a building list for Steele Lab, because there are groups in that building aside from CDS. We use cds-all instead.)

Graduate Students:

- ACM option: acm-grads@cms.caltech.edu
- CDS option: cds-grads@cms.caltech.edu
- CMS option: cms-grads@cms.caltech.edu
- CS option: cs-grads@cms.caltech.edu
- Visiting students and non-CMS students: misc-grads@cms.caltech.edu
- All grads across options: grads@cms.caltech.edu
- Women graduate students: gradcmswomen@caltech.edu

Departmental seminars:

- General CMS Seminars & Events: seminars@cms.caltech.edu
- IST Seminars: ist-seminars@cms.caltech.edu
- Weekly CMS Event Digest: thisweek@cms.caltech.edu

Research groups:

- RSRG: rsrg@caltech.edu
- DOLCIT: dolcit@caltech.edu
- CMX: cmx@caltech.edu
- SISL: sisl@caltech.edu
- CDS: cds-all@cds.caltech.edu

Who to ask for what

- Administrative questions: Maria Lopez, mlopez@cms.caltech.edu
- Office/Building related: Roberta Carvalho, robertac@caltech.edu