Graduate Student Handbook

2019 / 2020 Academic Year

Effective August 15, 2019

Ann & H. J. Smead Department of Aerospace Engineering Sciences

University of Colorado Boulder

1 Foreword

Aerospace Engineering Sciences (AES) is one of the top aerospace engineering departments in the nation. Aerospace engineers work on Earth and in space not only to extend frontiers but also to understand more fully and to preserve our terrestrial environment. Few fields offer more exciting and diverse careers: becoming an astronaut (fifteen CU graduates to date have become astronauts), designing the next generation of aircraft and spacecraft, monitoring our global habitat via remote sensing from space, inventing new materials, and helping to develop energy and transportation systems.

Our academic and research programs address both the challenges and the opportunities facing the aerospace engineering profession today. Graduate students, research staff and faculty work together on a wide range of research topics: aerodynamics and fluid mechanics; aerospace design and system engineering; astrodynamics and orbital mechanics; atmospheric, oceanic and space sciences; bioastronautics; computational and analytic methods; satellite-based global positioning/timing technology; remote sensing; structures, materials and structural dynamics; systems and control; and thermodynamics and propulsion.

Nearby government and industrial laboratories enhance the rich research environment of the University of Colorado Boulder. Local aerospace firms include Ball Aerospace, Lockheed-Martin, Northrop Grumman, Raytheon, and Sierra Nevada Corp. Nearby government laboratories include the National Center for Atmospheric Research (NCAR), the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration (NOAA), the National Renewable Energy Laboratory (NREL), and the National Institute of Standards and Technology (NIST).

In addition to the rules set forth in this Graduate Handbook, all students are also subject to the rules and provisions required by the University of Colorado Graduate School. These rules and provisions can be found on the Graduate School website here:

https://www.colorado.edu/graduateschool/academic-resources.

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2 Focus Areas

The MS and PhD programs in Aerospace Engineering Sciences are organized into five focus areas listed below. Graduate students are admitted into a specific focus area which provides research advising, sets specialized admission and program requirements, and recommendations for coursework both within and outside the department.

- Astrodynamics and Satellite Navigation Systems (ASN). This focus area investigates orbital motion of spacecraft, interplanetary mission design, attitude control, as well as navigation utilizing GNSS and advanced sensors.
- Autonomous Systems (AUT). This focus area draws from a variety of disciplines including robotics, human-robot interaction, artificial intelligence, unmanned systems, formal methods, and estimation and control theory.
- Bioastronautics (BIO). The study and support of life in space. Explores how to enable safe and efficient human space exploration.
- Fluids, Structures and Materials (FSM). This focus area studies the solid and fluid mechanics behind high-performance aeronautical and aerospace systems.
- Remote Sensing, Earth and Space Science (RSESS). Bridges the gap between science and engineering by exploring Earth from space, and space from Earth.

Many of our faculty members have interests in two or more of these areas and some students may end up doing research that spans multiple focus areas. Defining these areas enables specialization of the academic program in a sustainable way, aligned with primary research interests of the faculty. Furthermore, by bringing students directly into one of these groups we seek to facilitate and strengthen their connection with a primary advisor and with other like-minded students in the department.

Each focus area defines required characteristics of their successful graduates at the MS and PhD level and defines a set of required and elective courses to be offered on a regular basis that support their educational program. Each focus area is encouraged to look for synergy with other areas and other departments to avoid duplication and to enhance multidisciplinary education.

Specific information on each Focus Area, including their specific curriculum requirements, can be found in Appendix A

3 Key Contacts

Graduate Advisors: The graduate advisors are your first point of contact. They are intimately familiar with the policies of the graduate program at the Department, College, and University Level.

Graduate Program Advisors

Waleska Rivera-Shon (waleska.rivera-shon@colorado.edu)

Nicole Simmons (nicole.m.simmons@colorado.edu)

General inquiries: aerograd@colorado.edu

Graduate Chair: The graduate chair is the primary faculty member directing the graduate program.

Professor Marcus Holzinger

Associate Chair for Graduate Studies

Ann & H.J. Smead Department of Aerospace Engineering Sciences

marcus.holzinger@colorado.edu

Department Chair: The Department Chair oversees the entire department and all its programs.

Professor Brian Argrow

Department Chair

Ann & H.J. Smead Department of Aerospace Engineering Sciences

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4 Academic Standards

A master's degree student is required to maintain at least a B (3.00) average in all work attempted while enrolled in the Graduate School. Admission to PhD candidacy requires a 3.25 average. For both the master's degree and PhD, a course mark below B- is unsatisfactory and will not be counted toward fulfilling the minimum requirements for the degree.

Students who wish to drop a course after the drop deadline must show that they were unable to drop the course during the posted deadlines due to documented reasons that were beyond their control. An incomplete (I) grade is given only when students, for documented reasons beyond their control, have been unable to complete course requirements in the semester enrolled. A substantial amount of work must have been satisfactorily completed before approval of such a grade is given. At the end of one year, a grade of "I" given for a course that is not successfully completed or repeated is regarded as an F and shown as such on the student's transcript.

A student, who fails to maintain a 3.00 grade point average or to make adequate progress toward completing a degree, as assessed by the student's academic/research advisor, will be subject to suspension or dismissal from the Graduate School upon consultation with the AES Associate Chair for Graduate Studies. The final decision on suspension or dismissal will be made by the dean of the Graduate School.

Students should refer to the version of the Graduate Handbook in effect at the time of their matriculation for degree plan requirements. Students who are readmitted or continue on from the MS to the PhD program are subject to the handbook in effect at the time of their continuation start date.

Please visit the Graduate School website to view the current Rules:

https://www.colorado.edu/graduateschool/academic-resources.

In addition to rules contained within the 2019-2020 version of the Grad School handbook, the following two department-specific rules apply:

- PhD students are required to have a 3.25 GPA or above to be admitted to candidacy.
- Grades below a B- will not be counted towards degree requirements for any graduate students (MS or PhD).

5 Expectations

5.1 Student Expectations

We strive to maintain high standards within our Department, and all members of our Department to embody these expectations. Students will also strive to meet this "culture of excellence." Students are expected to want to learn, demonstrating enthusiasm, energy, and 100% effort. Writing should be clean and neat. Assignments should be completed on time and presented as a professional package. A lab book of activities and results should be well maintained.

As a full-time graduate student you are expected to engage in scholarly activities, defined as working in the laboratory, learning through discussions, going to seminars, taking courses, working at your desk, reading literature, writing publications and theses, and participating in university activities. Your professor is engaged in all these as well as research, advising, committee work, professional activities, and national & international service. Students should also strive to meet this "culture of scholarly excellence." Don't solely rely on your professors to tell you what you should be doing. Be proactive with your research and work and look for research areas to explore and expand.

Your presence at your desk, in the laboratory, and at seminars and meetings is a direct measure of your involvement in engineering and science. It is a privilege, opportunity, and responsibility to be a graduate student in AES.

Your attendance at department seminars, colloquia, and other presentations is an important part of your training as an engineer and scientist. This is an essential activity of all our scholars and we expect you to attend and participate in functions, especially those related to your area of research interest. You are also encouraged to present your research at seminars as opportunities arise.

We expect a professional and cordial atmosphere at all times and places. Be respectful and courteous to other students, staff, and faculty. Maintain a quiet work atmosphere; excessive noise distracts others. Assist your advisor and fellow graduate students. This is an important part of your training for the future. You will often be working in a group environment, so be a responsible team member. When you are required to share equipment with others, transfer data/codes/etc., do so in a professional manner. We expect that students follow the highest standards of ethics in their research and publications. Plagiarism, data manipulations, etc. are examples of unethical behavior and are not tolerated. Your adviser can help you and/or refer you to the proper channels if the ethical line is not clear.

5.2 Faculty expectations

Similarly, you may expect certain standards from your professors. It is the professor's responsibility to clarify their policies regarding time off, work hours, publication authorship, funding, etc. early on; it is your responsibility to make sure she/he does so. Your professors will guide you in your research, teaching, and professional development, and assist you with post-

graduation job placement. They will provide you with opportunities for industry or laboratory internships and encourage your attendance at professional conferences. Your professor will provide you with an annual evaluation of your progress in meeting your degree requirements and in your research, and if you have a Research Assistant appointment, financial support is guaranteed so long as you make acceptable progress (as determined by your advisor) and there are available funds.

5.3 Disagreements (non-grade-related)

For disagreements between a student and faculty member, initial concerns should first be addressed with the faculty member. If resolution cannot be reached, the Graduate Chair may be contacted to provide further guidance.

Students may elect to pursue resolution processes outside of the department at any point. Please consult the CU Boulder Graduate School policies, rules, and regulations for information about student grievance policies and procedures:

https://www.colorado.edu/graduateschool/current-students/graduate-school-policies-and-procedures

6 Master of Science Degree

The Master of Science degree is an advanced degree that aims to provide students further specialization after their Bachelor of Science degree. The MS degree at AES can be obtained following two different paths:

1. Traditional MS Program, where the study is aligned with one of the focus areas. It requires following the curriculum defined by the chosen focus area, plus either:

    a. Completion and defense of a MS thesis.

    b. Non-thesis course work, which can consist of (a) Graduate Projects I and II, (b) required courses leading to an approved certificate (or completion of the dual ASEN/EMP degree), or (c) courses as defined by each focus area.
2. Professional MS Program, which offers a more flexible course-based curriculum not aligned with the focus areas.

The next sections detail the requirements that are common to both the Traditional and Professional MS Programs, as well as those specific to each of the paths. Students in the BS/MS or BAM programs must also meet all the requirements of their chosen MS option.

6.1 Common Requirements for all MS options

- A total of 30 semester hours (including courses, and thesis hours), at least 24 semester hours of which must be completed at the 5000 level or above, with 18 credits in ASEN (CU courses beginning with ASEN XXXX). Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class.
- Up to 6 credits can be taken at the 4000 level in related engineering, math and science

departments (ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD). 4000 level ASEN courses are not counted toward the program.

- One of the approved math courses (3 semester hours) listed in Appendix B.
- Seminar credits, even those earned in other disciplines, do not count toward the MS degree.
- Completion of all degree requirements within four years from the date of commencing coursework, normally completed in one to two years.
- Master's degree residence requirements can be met only by residence on the CU Boulder campus for two semesters or three summer sessions, or a combination of at least one semester and two summer sessions. Residence in this context refers to a student's registration for CU Boulder courses. This does not apply to distance learning students.
- If a student is admitted on a provisional basis, a GPA of 3.25 must be maintained for each semester until 12 credit hours are completed, or the student will be suspended. Provisional students are required to take a minimum of 12 hours of graduate coursework over a period of 4 semesters. Additional conditions may be placed on a provisional student at the discretion of the department, to account for individual circumstances.

6.2 Transfer of credits for all MS students:

Up to 9 credits from an incomplete MS program may be accepted for degree requirements; however, work already applied toward a graduate degree received from CU Boulder or another institution cannot be accepted for transfer toward another graduate degree at the same level at CU Boulder. For example, work already applied to meet the requirements for a master's degree earned by a student cannot be used toward a second master's degree from CU. Also, undergraduate level credits cannot be transferred, including credits earned while in the BS program at CU and prior to matriculation into the masters or PhD programs. Transfer credit is any credit earned prior to matriculation into the graduate program. In addition, work completed for a doctoral degree may not be applied toward a subsequent master's degree. Extension work completed at another institution cannot be transferred; and correspondence work, except to make up deficiencies, is not recognized.

Up to 9 credits from the ACCESS and Be Boulder Anywhere (BBA) programs prior to matriculation will be accepted toward the MS degree. These credits do not have to be transferred, as they appear on the CU transcript. However, Continuing Education (non-degree) credits have to be transferred.

6.3 Professional Master of Science Degree

Students may elect to enroll in a Professional Master of Science (MS) degree rather than a traditional Master of Science, typically for one of the following reasons:

- Distance Learning students are interested in a coursework-only program.
- International and non-resident students are seeking a more affordable degree option.
- A student desires a more flexible and customized degree program (e.g. incorporating business courses) and/or does not wish to follow a specific focus area curriculum.

Professional Masters students are ineligible for salaried appointments (e.g., research or teaching assistantships), and any other university funding such as university fellowships.

6.4 Traditional MS Program Additional Requirements

In the Traditional MS program, students choose one of the Focus Areas for specialization. As a requirement, they must complete a series of courses designed by the Focus Area to provide the fundamentals of the field. This includes two to four required courses (6-12 semester hours) in the student's primary Focus Area and one required course (3 semester hours) that must be taken in a second Focus Area (or sub-track in some instances). More details for the specific course sequences can be found in Appendix A.

In addition, six more semester hours must be completed following one of the following options:

1. MS thesis option
2. Non-thesis course work option, which consist of one of the following:
    a. Graduate Projects I and II
    b. Required courses leading to an approved certificate (or completion of the dual ASEN/EMP degree)
    c. Courses as defined by each focus area. Details on all the options are presented next.

6.4.1 MS Thesis

The MS thesis must consist of original and independent research conducted by the graduate student under the supervision of the faculty advisor. The thesis topic must be related to the major field. The thesis must:

1. Represent the equivalent of 6 semester hours of coursework.

2. Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.

3. Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

The examination committee for the MS thesis will consist of three graduate faculty members.

For additional information, please see the Graduate School Rules:

https://www.colorado.edu/graduateschool/academic-resources

6.4.2 Non-Thesis Work: Graduate Projects

Graduate Projects (ASEN 5018/6028) is a two-semester course sequence designed to expose MS and PhD students to project management and systems engineering disciplines while working a complex aerospace engineering project as part of a project team. The course is also open to students in other engineering departments with the approval of the project professor. Graduate projects I and II is offered during the summer as a 6- credit course, and will count towards graduation requirements.

6.4.3 Non-Thesis Work: Certificate

In interdisciplinary certification programs, graduate students explore an interdisciplinary area while pursuing a master's or doctoral degree in a specific department. The students take classes outside their department and work with a faculty member affiliated with the program. Some programs also have research requirements. Professional certification programs allow professionals to pursue certification apart from degree completion. After completing the required work, students receive a certificate in the interdisciplinary field.

For detailed certificate information, see:

> https://www.colorado.edu/graduateschool/legacy-content/distance-education/certificate-programs

For a list of approved certificates, please see Appendix C. As an alternative to those, students can choose to complete the ASEN/EMP degree.

6.4.4 Non-Thesis Work: Focus Area-Defined Courses

Some Focus Areas offer the option to take additional courses to satisfy the non-thesis option. This will represent at least an additional six credit hours with respect to the minimum requirement to obtain a MS with that Focus Area. The details for each Focus Area can be found in Appendix A.

The traditional timeline over which students earn their PhD within our department has several distinct phases with subsequent examinations to transition between the phases. This process is outlined below.

7 Ph.D. Degree

7.1 Faculty Advisor

Prior to admission to the PhD program and during PhD studies, the student must have an AES graduate faculty advisor (the ‘faculty advisor,’ who must be a member of AES and the Graduate Faculty) who has agreed to supervise the student's dissertation research.

An advisor may choose to no longer serve as a student’s faculty advisor by providing written electronic notice to the student and the Associate Chair for Graduate Studies. To remain within the PhD program a student without a faculty advisor must obtain a new AES graduate faculty advisor within 120 days of notice from the previous advisor. To satisfy this time limit the new student faculty advisor must provide written electronic notice indicating their willingness to serve as the student’s faculty advisor to both the student and the Associate Chair for Graduate Studies. If the student is unable to find a new faculty advisor within 120 days the student will be removed from the PhD program; If the student does not already possess a M.S. degree, then rather than dismissal from the PhD program their degree program will be changed to the M.S. program.

A student entering the PhD program in Aerospace Engineering Sciences is not required to possess an MS degree; however, the student must have the proficiency of an individual who has earned an MS degree given in the Department of Aerospace Engineering Sciences at the University of Colorado in order to pass the preliminary examination. After passing the preliminary examination, a student is considered a PhD pre-candidate. Once passed, the student is admitted to candidacy and officially becomes a PhD candidate.

7.2 Program Requirements

Program Requirements encompass required aspects of coursework, examination, and timeline for PhD completion. The following are the program course requirements for PhD degree completion:

- A total of 30 course credits numbered 5000 or above with 9 of these taken at the 6000 level or above. A 4000-level course cannot be applied to the PhD. Course curriculum is defined by the chosen focus area and approved by the faculty advisor. See, focus area curricula charts in Appendix E for more information.
- A minimum cumulative GPA of 3.25. A student who fails to maintain a 3.25 grade point average or to make adequate progress toward completing a degree, as assessed by the student's advisor, will be subject to suspension from the Graduate School upon consultation with the major department. The final decision on suspension will be made by the dean of the Graduate School.
- At least 15 credits must be in ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class). Seminar credits, even those earned in other disciplines, do not count toward the PhD degree.
- At least 6 credits of approved math courses (see list of approved math courses in Appendix B.
- Up to 21 credits from an outside MS program can be applied. All credits earned from a MS program taken at the University of Colorado can be applied toward a PhD. MS thesis credits cannot be applied to the PhD regardless of the institution where the MS was earned.
- At least 30 PhD dissertation credits. A student must register for a minimum of five dissertation hours in the fall and spring semesters of each year, beginning with the semester following the passing of the comprehensive exam and extending through the semester in which the dissertation is successfully defended (final examination). (See Graduate School Rules for additional information: https://www.colorado.edu/graduateschool/academic-resources)
- For the PhD, a course mark **below B- is unsatisfactory** and will not be counted toward fulfilling the minimum requirements for the degree.

In addition to these course requirements, students must also pass a series of examinations. Students must pass a departmental preliminary examination, or its equivalent: A) no later than the end of the 3rd semester as a CU graduate student if the student already has a master's degree in aerospace engineering; B) no later than the 5th semester as a CU graduate student if the student does not already have a master's degree in aerospace engineering. Students must pass a comprehensive examination: A) no later than the end of the 5th semester if the student already has an aerospace master's degree; B) the 7th semester if the student does not already have an aerospace master's degree. Note that students must have completed or be enrolled in the remaining courses to complete the 30 required course credits by this semester. Students cannot be admitted into candidacy until the necessary coursework is complete. The Graduate School requires the accumulation of PhD dissertation credits within the maximum 6 year program length to complete the PhD. For additional information, see Graduate School Rules: https://www.colorado.edu/graduateschool/academic-resources. Finally, students must complete a PhD dissertation and successfully defend the dissertation in a final examination.

The minimum residence requirement for a PhD is six semesters beyond the attainment of an acceptable bachelor's degree (2 semesters from another institution may be counted towards this requirement). ”Residence” in this context refers to a student’s registration for CU-Boulder courses, and not physical residence. All degree requirements must be satisfied in a period of 6 years from the commencement of coursework for the PhD.

7.3 Teaching Practicum

All PhD students are expected to gain teaching experience through a Teaching Practicum. The teaching practicum reflects one semester of documented teaching experience for each PhD student. It may be fulfilled in a number of ways to allow flexibility to the student and their advisor based on interests, skills, and departmental needs. While some teaching activities might be paid assignments from the department (for example, a teaching assistantship or hourly course assistantship), there is no requirement for the teaching practicum to be a paid appointment.

Examples of 1 semester teaching practicum activities:

- Teaching Assistant
- Teaching Fellow or Course Assistant (hourly)
- Team-teaching a course with an AES faculty member
- Mentor responsible for UROP, Discovery Learning Apprentice, SURE or SMART student or high school student, for full summer or semester
- Coordinator for focus area seminar

The advisor is responsible for specifying the teaching activities required and providing guidance and assistance to the student in this work. For teaching as a research mentor the advisor should set clear expectations for the role of the graduate student mentor and ensure that both the graduate mentor and the undergraduate student(s) they are working with understand the responsibilities and roles of each. Students must complete the teaching practicum tracking sheet available in Appendix E, prior to or in the semester of their final defense.

7.4 Preparation for the Preliminary Exam (Years 1-2)

During the first two years of the PhD program students take coursework needed for academic preparation, begin conducting research with their advisor, and possibly complete their teaching practicum.

7.4.1 Preliminary Exam

The **Preliminary Exam** (prelim) evaluates students’ academic qualifications and competency in relevant subject areas for entrance into the PhD program. The goal is to ensure that all students continuing in the program have the technical and communications skills required for successful completion of the doctorate.

A student must have a faculty advisor (see section 7.1) to take the preliminary examination.

7.4.2 Subject Matter

The prelim examination committee consists of three ASEN faculty members selected by the student, including the PhD advisor, each of which will examine the student in a different topic. The student must select two topics from the student's focus area and a third topic from an out-of-focus area. The topics covered for each focus area or sub-track must be selected from the core courses listed in Appendix A. If a course is listed under two or more focus areas, it cannot be taken as an out-of-focus area topic. Alternate courses must be approved via petition.

The committee members determine the topical coverage of the exam for each student. In general, it will include MS level coursework and undergraduate prerequisite material relevant to the student's and committee members' focus areas. The exam questions may also address relevant research topics, background material, and integration of material from several courses. Students are expected to discuss expectations for the exam with each of the faculty members they select for their committee. The primary advisor may choose an alternate oral exam format, such as reading and discussing a research paper on the selected topic. However, the student must be given at least a week notice on such reading assignments.

7.4.3 Logistics

The exam comprises a written and oral component, both administered by the student's prelim committee. The student's faculty advisor should be the committee chair. Students must return the Preliminary Exam form to the graduate advisors by the posted deadline with the names of the three faculty members they have asked to sit on the committee. Each faculty member will ask one or more questions on both the written and oral exams. The written exam is typically given each year between August 15 and September 15. Unless otherwise noted, the exam is closed- book and closed notes and has a duration of 6 hours. Students can bring up to 3 pages of notes, which are written on 8.5" x 11" paper and can have notes on both sides. The student is responsible for scheduling an oral exam to take place within 2 weeks of the written component of the exam. The oral exam has a duration of up to 2 hours.

Students are NOT allowed to discuss the preliminary examination with ANYONE until after ALL preliminary examinations are completed within AES – written and oral. Failure to abide by this rule is an Honor Code violation.

7.4.4 Grading

The committee will provide an overall recommendation on the student's progress, and determine one of the following outcomes:

- Preliminary examination is passed unconditionally
- Preliminary examination has conditions placed. Committee-specified conditions must be satisfied before 30 days after the next exam offering (annually in the Fall semester).
- Preliminary examination was unsatisfactory. Students who fail the exam may retest at the next exam offering. Students who fail to pass the exam after the second attempt will be dismissed from the PhD program.

Committee members will evaluate the examinee based on the following parameters:

1. Written exams – Each member will grade the written exam on a 0-100%

   scale before holding the oral examination. The lead committee member takes the written

scores and records the cumulative level of competency (satisfactory / marginal / unsatisfactory) on the prelim form in the written exam line. All members will hold on to the graded exams as they may want to revisit questions during the oral exam.

2. Oral exams – Each member participates in the oral exam. Before the oral

   exam starts, the student is briefly dismissed so all committee members can discuss the written exam outcome. Upon completion of the exam, committee members record a cumulative level of competency satisfactory/marginal/unsatisfactory) on the prelim form in the oral exam line.

3. Pass / Conditional Pass / Fail – After the oral examinations are completed,

   the committee will make its final decision on whether the student passes unconditionally, with conditions, or fails. The lead committee member will notify the student of the outcome.

The preliminary examination committee also considers the student's research and/or teaching abilities into its final decision.

7.5 The Comprehensive Exam and Admission to Candidacy (Years 2-3)

In the second and third year of the program, PhD students who have successfully passed the Preliminary Exam work on advancing their specialized technical expertise. In collaboration with their advisor, students begin the process of defining their specific doctoral research topic.

The Comprehensive Exam tests mastery of a broad field of knowledge, not merely formal coursework. It includes both written and oral elements, which together test the student's depth of understanding of their technical area.

7.5.1 Comprehensive Examination Requirements & Logistics

Before admission into doctoral candidacy, students must pass a comprehensive examination. Students are responsible for scheduling the exam in conjunction with their faculty advisor and committee members.

The following are additional requirements for the comprehensive examination:

- A student shall have earned at least four semesters of Residence (see PhD program requirements), have a GPA of 3.25 for all graduate ASEN or CU coursework, and shall have passed the Comprehensive Examination before admission to candidacy is approved by the Graduate School.
- The Comprehensive Examination must be taken at least one semester before the Final Exam.
- At least one week before the exam, the candidate must provide each member of the thesis committee the written proposal for thesis research.

The Comprehensive Exam is administered by a Thesis Committee (see section 7.5.2). This committee will serve as the examining board for both the Comprehensive Examination and Final Defense Examination.

Two weeks prior to the exam students submit a Candidacy Application for An Advanced Degree and a copy of the Doctoral Examination Report form listing their committee members to their Graduate Program Advisor. Forms can be found here:

https://www.colorado.edu/graduateschool/legacy-content/academic-forms.

The Doctoral Exam form will be returned to the student after it's approved by the Graduate School. Students should bring the approved form to their comprehensive examination for committee members to sign.

One week prior to the exam the student must provide committee members electronic copies of their written proposal (see section 7.5.4).

After the examination the completed exam form is returned to the Graduate Program Advisor.

7.5.2 Thesis Committee Composition

The thesis committee is composed of at least 5 individuals, which must include 3 Tenured, Tenure-Track, Research, Adjunct or Adjoint AES professors (not including instructors, or those with special appointments) and 1 external (non-AES) member.

Non-CU persons must be approved by the Graduate School; consult with your Graduate Program Advisor at least one month prior to the comprehensive or thesis exam if you wish to include non-CU persons on the committee. Additional paperwork may be required for them to serve on the committee.

Professors from other departments who hold courtesy appointments in AES can be included as either internal or external members, but not both. Each student should work with their advisor to identify suitable faculty members to serve on the committee.

The student's faculty advisor serves as the Thesis Committee Chair unless a conflict of interest or other extenuating circumstance has been identified.

7.5.3 Written Research Proposal

The written element consists of a research proposal (15-20 pages) that demonstrates the student's capacity for scholarly work in their chosen topic and includes a timeline for proposed research tasks.

A successful written research proposal and examination convinces the thesis committee that the candidate has:

- A thorough understanding of the research literature in the chosen field
- Articulated an original and significant research program
- Familiarity with the tools and methods of the proposed research
- Identified a project that is of the appropriate scope for a PhD thesis
- A reasonable plan to complete the research in the time period allowed for the PhD requirements.

Typically, a successful candidate will have conducted some preliminary research on the thesis topic prior to the examination, and these preliminary results should be included in the research proposal.

7.5.4 Oral Examination Format

The oral exam includes a presentation by the student defending their written proposal and addressing questions from the thesis committee and other faculty who may attend. The oral presentation and committee questions will take approximately 2 hours. The student should prepare a presentation to be about 45 minutes and address the following questions:

- Why is the proposed research of interest, how does it compare to prior work?
- Is the proposed research challenging enough to be worthy of a PhD dissertation?
- Is the student qualified and knowledgeable enough to perform the proposed work?
- Are the timeline and the scope of the proposed work reasonable?

The remainder of the exam consists of questions directed to the candidate by the committee members. The questions typically pertain to the subject matter and content of the proposal, but may also be asked on topics outside this area, at the committee's discretion.

The outcome of the comprehensive exam is determined by Graduate School procedures. Students who successfully pass this exam then are considered PhD Candidates. A successful candidate must receive the affirmative votes of the majority of the members of the examining board. In case of failure, the examination may be attempted once more after a period of time determined by the thesis committee. The student is automatically dismissed by the Graduate School after a second failure. Details on the Comprehensive Examination format can be found on the Graduate School Rules: https://www.colorado.edu/graduateschool/academic-resources

7.6 Dissertation Research & Teaching (Years 3 and beyond)

In the subsequent years of the program, the PhD candidate will work with the faculty to conduct research which includes writing and presenting technical papers at conferences and in journals, reviewing technical papers, writing research proposals, and mentoring undergraduate, MS, or new doctoral students. They will also take advanced coursework and complete their teaching practicum. Both the advisor and student are responsible for ensuring that the work is adequately progressing. The student will meet with each of the members of their thesis committee at least once per semester to assess progress and to obtain feedback.

7.6.1 PhD Dissertation

The dissertation document is based upon original investigation, shows mature scholarship and critical judgment, and demonstrates familiarity with the tools and methods of the research. The dissertation document must be written upon a subject approved by the student's thesis committee chair. Each dissertation presented in partial fulfillment of the doctoral degree must:

- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications: https://www.colorado.edu/graduateschool/academic-resources
- Be filed with the Graduate School by the posted deadline for the semester in which the degree is to be conferred.

7.6.2 Final Examination

After the dissertation has been accepted by the student's committee a final examination of the dissertation and related topics will be conducted. The following requirements must be satisfied:

- A student must be registered as a regular degree student on the Boulder Campus for a minimum of five, and no more than ten, dissertation hours the semester in which the final examination is scheduled.
- The examination will be oral and open to anyone who wishes to attend
- The examination will be conducted by the same dissertation committee in place for the comprehensive exam.
- More than one dissenting vote will disqualify the candidate. In case of failure, the examination may be attempted only one more time. A second failure will result in automatic suspension by the Graduate School. Signatures from all committee members are required.
- Two weeks prior to the exam students submit a copy of the Doctoral Examination Report form listing their committee members to their Graduate Program Advisor. These forms can be found at: https://www.colorado.edu/graduateschool/legacy-content/academic-forms. The Doctoral Exam form will be returned to the student after it's approved by the Graduate School. Students should bring the approved form to their final examination for committee members to sign. After the examination, the completed exam form should be returned to the Graduate Program Advisor.

See the Graduate School Rules for additional information:

https://www.colorado.edu/graduateschool/academic-resources

8 Appointments

Students can be supported by the Department with three different types of positions:

- Salary compensation, by semester, with tuition support: Research Assistant (RA) and Teaching Assistant (TA).
- Salary compensation, by semester: Teaching Fellows (TF).
- Hourly paid positions, for research, grading or other activities in the department.

Additionally, students can also be supported through external fellowships, or with personal funds.

8.1 Appointment percentage

The majority of department RA/TA/TFs have a 50% AY appointment (20 hrs/wk). Some may have summer appointments (up to 40 hrs/wk) but this is determined by the supervisor. A RA/TA can hold no less than a 15% appointment to receive tuition remission. Any appointment in addition to a 50% appointment needs special approval by the Graduate School.

8.2 Tuition

Tuition remission is provided for RA and TA appointments. It covers tuition and a percentage of the Gold Comprehensive Insurance Plan, provided that you work at least 12 weeks of the semester. It is your responsibility to pay the remainder of the insurance and all mandatory fees. Some fellowships do allow for the payment of fees, but department appointments do not.

8.3 Appointment Periods

The appointment follows the University holiday schedule and not the class schedule: https://www.colorado.edu/hr/home/cu-boulder-holiday-schedule. Please note that these dates are distinct from the first and last dates of instruction identified in the Academic Calendar.

Fall - August 15 through December 31

Spring - January 1 through May 15

Summer - May 16 through August 14

For example, the University is officially closed only on the Friday of spring break, not for the entire spring break week; so unless you make arrangements with your advisor, you are expected to work during the week of spring break even though there are no classes that week.

8.4 Leave

Students on appointment do not accumulate sick or vacation time through their appointment. There is not a policy within the department regarding sick or vacation time; this policy is set directly by your supervisor.

It is up to the student to discuss taking time off with your supervisor before making travel arrangements or arranging for time off. If you will be away from your position for an extended period of time, your supervisor does have the option to put the position on a short work break, without pay. This does not happen often, but it is an option.

Appendix A.Focus Area Curricula

A.1 Astrodynamics and Satellite Navigation Systems (ASN)

ASN Specific MS Requirements
Three ASN Core Classes
One ASEN MS Course from an outside (non-ASN) AES focus area

Required (Core) MS Courses in Focus Area:

Course Number (current)	**Title (faculty who teach)**	**Offering (F - Fall, S – Spring, A – annually, B – biennially)**
ASEN 5010	Attitude Dynamics and Control	S, A
ASEN 5050*	Space Flight Dynamics	F, A
ASEN 5090	Introduction to GNSS	F, A
ASEN 5044	Statistical Estimation for Dynamical Systems	F, A

*ASEN 5519: Analytical Astrodynamics is an alternative option to ASEN 5050. ASEN 5519: Analytical Astrodynamics will satisfy the same requirements and prerequisites as ASEN 5050.

Elective Courses offered by Focus Area:

Course Number (current)	**Title**	**Offering (F - Fall, S – Spring, A – annually, B – biennially, T - triennially)**
ASEN 6070	Satellite Geodesy	F/B
ASEN 6080	Advanced Statistical Orbit Determination	S/A
ASEN 6008	Interplanetary Mission Design	A, S
ASEN 6020	Optimal Trajectories	F/T
ASEN 6010	Advanced Spacecraft Dynamics and Control	F/B
ASEN 6014	Spacecraft Formation Flying	F/B

Course Number (current)	**Title**	**Offering (F - Fall, S – Spring, A – annually, B – biennially, T - triennially)**
ASEN 6060	Advanced Astrodynamics	F/T
ASEN 6090	Advanced GNSS Software	S/B
ASEN 6091	Global Satellite Navigation System (GNSS) Receiver Architecture	S/B
ASEN 6519	GNSS for Remote Sensing	S/B
ASEN 6519	Celestial Mechanics & Advanced Astrodynamics	F/T

A.2 Autonomous Systems (AUT)

AUT Specific MS Requirements

Students must take one course from three of the following topics:

Control Theory

ASEN 5014 Linear Control Systems

ASEN 5024 Nonlinear Systems

Estimation and Sensor Fusion

ASEN 5044 Statistical Estimation for Dynamical Systems

Dynamics and Modelling of Vehicles

ASEN 5519 System Identification

ASEN 5519 Small UAS Dynamics and Control

Autonomous Decision-Making

ASEN 5519 Autonomy for Aerospace Systems

ASEN 5519 Algorithmic Motion Planning

Programming for Embedded Systems

ASEN 5519 Microavionics

MCEN 5115 Mechatronics and Robotics

ECEN 5613 Embedded System Design

ECEN 5813 Principles of Embedded Software

CSCI 5302 Advanced Robotics

AUT Course-only MS Requirements

Satisfaction of the AUT Specific MS Requirements plus two additional courses from two different topic areas. (Note: the two additional topic areas can be the same areas used to satisfy the Specific MS requirement).

AUT Specific PhD Requirements

Satisfaction of the AUT Specific MS Requirements.

Elective Courses offered by Focus Area:

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially, T - triennially)
ASEN 5519	Multi-Object Filtering Theory	Varies
ASEN 6519	Cooperative Control of Multi-Vehicle Systems	Varies
ASEN 6519	Model-Based Parameter & State Estimation	Varies
ASEN 6519	Hybrid Control Systems	Varies

Example Elective Courses offered outside Focus Area:

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially, T - triennially)
CS	Machine Learning	
ECEE	Multi-agent Control	
CS	Convex Optimization	
ECEE	Sampled Data Systems	
CS	Computer Vision	
ME	Robust, Multivariable Control	

A.3 Bioastronautics (BIO)

Bio Specific MS Requirements

ASEN 5016 Space Life Sciences

ASEN 5158 Space Habitat Design

One of four:

ASEN 5519 Medicine in Space and Surface Environments

ASEN 6116 Spacecraft Life Support Systems

ASEN 6519 Human Operation of Aerospace Vehicles

ASEN 6519 Extravehicular Activity

One of three:

ASEN 5335 Aerospace Environment (RSESS)

ASEN 5050 Space Flight Dynamics (ASN)

ASEN 5053 Rocket Propulsion (VS)

Bio Specific PhD Requirements

This specialized field of study addressing human spaceflight is typically augmented with coursework tailored to meet the student's specific career interests, and may include related topics in spacecraft engineering design, life sciences or other areas relevant to the needs of the research.

ASEN 5016 Space Life Sciences

ASEN 5158 Space Habitat Design

Required MS Courses in Focus Area:

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5016	Space Life Sciences	S, A
ASEN 5158	Space Habitat Design	F, A

Required MS Courses outside Focus Area (any 1 of 3)**:**

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5335	Aerospace Environment	S, A
ASEN 5050†	Space Flight Dynamics	F, A
ASEN 5053	Rocket Propulsion	F

†ASEN 5519:Analytical Astrodynamics is an alternative option to ASEN 5050. ASEN 5519: Analytical Astrodynamics will satisfy the same requirements and prerequisites as ASEN 5050.

Elective Courses offered by Focus Area:

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5519	Experimental Design and Statistical Methods	Varies
ASEN 6116	Spacecraft Life Support Systems	Varies
ASEN 6519	Extravehicular Activity	Varies
ASEN 6519	Human Operation of Aerospace Vehicles	Varies
ASEN 5519	Medicine in Space and Surface Environments	Maymester, A
ASEN 5849	MS Independent Study	on request
ASEN 6849	Independent Study (for PhD 'pre/non-thesis' topic)	on request

A.4 Fluids, Structures and Materials (FSM)

The Fluids, Structures and Materials (FSM) Focus Area is further divided into two tracks: (1) Fluids, and (2) Structures and Materials.

FSM Specific MS Requirements

- Two Core Classes in your chosen FSM track, and one core course in the other FSM track.
- Two electives from the FSM focus area, with at least one in your chosen track.
- Attending 50% of the "Fluid, Structures and Materials" seminars each semester.

FSM Course-only M.S. Requirements

Satisfaction of the FSM Specific MS Requirements plus one additional core course and one additional elective from the FSM courses listed below.

FSM Specific PhD Requirements

- Two Core Classes in your chosen FSM track.
- Attending 50% of the "Fluid, Structures and Materials" seminars each semester

Note: For the purposes of the AES Preliminary Exam and other AES department policies, students ***can*** use core courses from the other track from which they are enrolled within the FSM Focus Area to satisfy an *out of Focus Area* requirement (core courses are listed below).

Core Courses Offered by Focus Area:

Fluids:

- ASEN 5051 Intro to Fluid Mechanics (fall offering) (Note: changing to "Incompressible Flow")
- ASEN 5151 High Speed Aerodynamics (spring offering) (Note: changing to "Compressible Flow")
- ASEN 6037 Turbulent Flow (spring offering)

Structures and Materials:

- ASEN 5012 Mechanics of Aerospace Structures (fall offering)
- ASEN 5022 Introduction into Dynamics of Aerospace Structures (spring offering)
- ASEN 5007 Introduction into Finite Elements (fall offering)

Elective Courses offered by Focus Area:

Fluids

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5053	Rocket Propulsion	S-O
ASEN 5063	Aircraft Propulsion	F-E
ASEN 5519	Boundary Layers, Convection, and Applied CFD	S-O
MCEN 6001	Reacting Flows	S-E
ASEN 6321	Computational Fluid Dynamics Structured Grid	F-E
ASEN 6331	Computational Fluid Dynamics Unstructured Grid	F-O
ASEN 6519	Experimental Fluid Mechanics	F-E
ASEN 6061	Molecular Gas Dynamics and Direct Monte Carlo Simulation	Varies
ASEN 6519	Advanced Turbulence Simulation	Varies
ASEN 6519	Flow Control	Varies
ASEN 6519	Stabilized and Multiscale Finite Element	Varies
ASEN 6519	Mathematical Foundations of Finite Element Analysis	Varies
ASEN 6519	Isogeometric Analysis	Varies

Structures and Materials:

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5111	Aeroelasticity	S, B
ASEN 5148	Spacecraft Design	S, A
ASEN 5218	Large Space Structures Design	Varies
ASEN 5519	Design Optimization in Aerospace Systems	S, B
ASEN 5519	Introduction to Phononics	F, B
ASEN 5519	Inverse Methods	Varies
ASEN 5519	Classical Thermodynamics	Varies
ASEN 5519	Deploy and Lightweight Structures	Varies
ASEN 5519	Molecular Dynamics	Varies
ASEN 5188/ Same as EMEN 5405	Space Systems Engineering	S
ASEN 6024	Nonlinear Systems	B, S
ASEN 6519	Isogeometric Analysis	Varies
ASEN 6519	High Performance Computing	B
ASEN 6517	Computational Methods in Dynamics	Varies
ASEN 6107	Nonlinear Finite Elements	S, B
ASEN 6367	Advanced Finite Elements for Plates & Shells	S, B
ASEN 6519	Engineering Nonlinear Dynamics	S, B
ASEN 6412	Uncertainty Quantification	S, B
ASEN 6519	Cooperative Control of Multi-Vehicle Systems	Varies

A.5 Remote Sensing, Earth and Space Science (RSESS)

The expected competency at the graduating masters level in the RSESS focus area is to have completed coursework in four primary topics of study (1) Data or Numerical Analysis Methods, (2) Instrumentation Fundamentals, (3) Physical Sciences of Earth and Space and (4) Astrodynamics or Aerospace Engineering Systems.

The below requirements are applicable to both MS and PhD candidates in the RSESS focus area.

The expected competency at the PhD level is to further advance the four primary topics within RSESS by complementary theory and analysis obtained through coursework offered at the 6000 level and above, and by research activities in developing the PhD thesis.

Required courses needed to specialize in the RSESS focus area are:

- One course in data or numerical analysis
- One course in instrumentation
- One course in physical science
- One course in astrodynamics or aerospace engineering systems

MS students using the Remote Sensing Certificate for their degree requirements in lieu of an MS thesis or two semester graduate projects may count a maximum of 2 of the 4 required RSESS focus area courses toward the certificate requirement.

Below is a list of RSESS Primary courses that satisfy the four primary topics. These courses are listed here as their content satisfies a primary topic in our focus area. Students can design a course schedule with their graduate faculty advisor to ensure their course selections satisfy the RSESS focus area. It is possible to petition courses outside of these RSESS Primary courses to fulfill the required coursework as long as they meet the four topics of study outlined above and that the general guidelines of the AES graduate program are met. A subset of RSESS Primary courses are designated as RSESS Core courses for the purpose of AES Preliminary Exam.

RSESS Data or Numerical Analysis Courses (1):

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5307	Engineering Data Analysis	S-A
ASEN 6337	Remote Sensing Data Analysis	F-B
ASEN 6055	Data Assimilation & Inverse Methods for Earth and Geospace Observations	F-B
APPM 5540	Introduction to Time Series	S-B
APPM 5580	Introduction to Statistical Learning	S-A
APPM/STAT 5520	Introduction to Mathematical Statistics	F-A
APPM 5570	Statistical Methods	F,S-A
APPM 5350	Methods in Applied Mathematics: Fourier Series and Boundary Value Problems	F-A
ECEN 5612	Noise and Random Processes	F-A
ECEN 5632	Theory and Application of Digital Filtering	F-A
ECEN 5652	Detection and Extraction of Signals from Noise	S-A

RSESS Instrumentation Courses (2):

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5090	Introduction to Global Navigation Satellite Systems	F-A
ASEN 5245	Radar and Remote Sensing	S-A
ASEN 5440	Space Mission Development	B-F
ASEN 6050	Space Instrumentation	F-B
ASEN 6365	Lidar Remote Sensing	Varies
ASEN 6265	Fundamentals of Spectroscopy for Optical Remote Sensing	Varies
ASEN 5519	Microavionics	Varies
ASEN 5168	Remote Sensing Instrumentation	

RSESS Physical Sciences Courses (3):

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5335	Aerospace Environment	S-A
ATOC/ASEN 5235	Introduction to Atmospheric Radiative Transfer and Remote Sensing	S-A
ATOC 5060	Dynamics of the Atmosphere and Ocean	S-A
ATOC 5051	Introduction to Physical Oceanography	F-A
ATOC 5050	Atmospheric Thermodynamics and Dynamics	F-A
ASTR 5140	Astrophysical and Space Plasmas	F-B
ASTR 5150	Introduction to Plasma Physics	S-A
ASTR 5300	Introduction to Magnetospheres	S-A
ASEN 6519	Special Topics in Aerospace Environment: Upper Atmospheres	Varies

RSESS ASN or AESys Courses (4):

Course Number (current)	Title	Offering (F - Fall, S – Spring, A – annually, B – biennially)
ASEN 5014	Linear Control Systems	F-A
ASEN 5050	Space Flight Dynamics	F-A
ASEN 5051	Intro to Fluid Mechanics	F-A
ASEN 5148	Spacecraft Design	S-A
ASEN 6070	Satellite Geodesy	F-B
ASEN 5044	Statistical Estimation for Dynamical System	F,S-A

Below is a list of approved Core RSESS courses that can be used for AES Preliminary Exam. At least two RSESS Core courses are offered every year.

RSESS Core Courses (6):

- ASEN 5335 Aerospace Environment
- ASEN 5235 Introduction to Atmospheric Radiative Transfer and Remote Sensing
- ASEN 5307 Engineering Data Analysis
- ASEN 5245 Radar and Remote Sensing
- ASEN 6050* Space Instrumentation
- ASEN 6365 Lidar Remote Sensing
- ASEN 6265 Fundamentals of Spectroscopy

*ASEN 6050 can be used for AES Preliminary Exam only after 2020.

Appendix B. List of Approved Math Courses

- ASEN 5227: Aerospace Math
- ASEN 5307: Engineering Data Analysis Methods (can be used to meet only one curriculum-specific requirement, i.e. math or RSS core/RSS certificate.)
- ASEN 5417: Numerical Methods for Differential Equations
- ASEN 5044: Statistical Estimation for Dynamical Systems (can be used to meet only one curriculum-specific requirement, i.e. math or ASN core and ASN certificate.)
- ASEN 5519: Multi-Object Filtering Theory
- ASEN 5519: Experimental Design and Statistical Methods
- ASEN 6412: Uncertainty Quantification (can be used to meet only one curriculum-specific requirement)
- EMEN 5005: Intro to Applied Statistical Methods
- APPM 4000, 5000, 6000, 7000 level courses
- MATH 4000, 5000, 6000, 7000 level courses
- ECEN 5612: Noise and Random Processes
- ECEN 5632: Theory and Application of Digital Filtering
- ECEN 5642: Modern Methods of Spectral Estimation
- ECEN 5652: Detection and Extraction of Signals from Noise

Appendix C. AES Department Certificates

C.1 Certificate in Remote Sensing

Remote sensing (satellite and ground-based) is increasingly being used as a technique to probe the Earth's atmosphere, ocean and land surfaces. Probing of other planets is accomplished largely by satellite remote sensing. Given national priorities in such areas as climate and global change, the interest in remote sensing will only increase with time.

Remote sensing is a relatively new academic subject, with few universities having any sort of an organized curriculum. The purpose of formalizing the CU remote sensing curriculum is to coordinate curricula across campus so that a coherent curriculum in remote sensing can be provided to complement and supplement the students' regular degree program. An additional purpose is to encourage multidisciplinary education of the students in the area of remote sensing.

Graduate students, research staff, and faculty work on a wide variety of topics, ranging from the theory of remote sensing, to its application. These applications include: use of satellite remote sensing to determine ocean surface temperature and heat fluxes; use of surface radar to improve the determination of clouds and precipitation from satellite; determination of surface biological characteristics and productivity from satellite; mapping of land use from satellite; mapping of surface landform and topographical features; searching for locations of buried artifacts; use of surface radar to determine upper atmosphere wind motions; and aircraft remote sensing to assess the validity of satellite retrieval algorithms of surface and atmospheric characteristics.

Certificate Requirements

- Four courses are required totaling at least 12 credits, with grades of B or better.
- Two courses from one of the following topical areas:

    a. Data Analysis

    b. Instrumentation and Measurement Techniques

    c. Remote Sensing Theory

- One course in each of the two remaining topical areas
- At least one semester of Remote Sensing Seminar (currently listed as ASEN 5210 and ATOC 7500).

Data Analysis Courses:

- ASEN 5307 Engineering Data Analysis
- ASTR 5550 Observations, Data Analysis, and Statistics
- ECEN 5004 Environmental Signal Processing
- ECEN 5254 Remote Sensing Signals and Systems
- ECEN 5612 Noise and Random Processes
- ECEN 5652 Detection and Extraction of Signals from Noise

- GEOG 5103 Intro to Geographical Information Systems
- GEOG 5203 GIS and Spatial Modeling
- GEOG 5303 GIS Programming for Spatial Analysis

Instrumentation & Measurement Techniques Courses:

- ASEN 5168 Remote Sensing Instrumentation Design
- ASEN 5245 Radar and Remote Sensing
- ASEN 6091 GNSS Receiver Architecture
- ASEN 6365 Lidar Remote Sensing
- ASTR 5760 Astrophysical Instrumentation
- ECEN 5134 Electromagnetic Radiation and Antennas
- ECEN 5274 Radar Science and Techniques
- PHYS 5160 Fundamentals of Optics and Lasers
- ASEN 6050 Space Instrumentation
- GEOG 5100 Adv. Measurements in Snow Measurement

Remote Sensing Theory Courses:

- ATOC/ASEN 5235 Intro to Atmos Rad Trans & Remote Sens
- ASEN 6265 Fundamentals of Spectroscopy
- ATOC/ASTR 5560 Radiative Processes in Planetary Atmosphere
- ECEN 5264 Electromag Absorption, Scattering & Propagation
- GEOL/GEOG 5093 Remote Sensing of the Environment
- GEOG 5100 Advanced Remote Sensing
- PHYS/ASTR 5150 Plasma Physics

Admission Requirements

Requirements for a Graduate Certificate in Astrodynamics and Satellite Navigation Systems:

- Email aerograd@colorado.edu to be registered as a certificate-seeking student.
- Completion, with a grade of B or better, of all required courses.
- Upon completion of your courses, complete the certificate request form and submit it to the Graduate Advisor, aerograd@colorado.edu.

C.2 Certificate in Astrodynamics and Satellite Navigation Systems (ASN)

The certificate recognizes student accomplishments at the graduate level in successfully completing a specialized program of study in Astrodynamics and Satellite Navigation (ASN). It is essentially a specialization of the Aerospace Engineering Sciences Master of Science (MS) degree in the ASN focus area with additional requirements for breadth and depth in the ASN area.

The certificate will make students more desirable to prospective employers looking for astrodynamics and satellite navigation specialists.

Certificate Requirements

Complete all four core area subjects in ASN, plus two advanced ASN courses of the student's choosing.

Core Requirements:

ASEN 5010 - Spacecraft Attitude Dynamics and Control

ASEN 5050 – Astrodynamics †

ASEN 5044 - Statistical Estimation for Dynamical Systems

ASEN 5090 - Introduction to Global Navigation Satellite Systems

*Any core requirement can be satisfied by taking an additional 6000 level course which has the corresponding core requirement as a prerequisite. *This substitution does not require a petition.*

† ASEN 5519: Analytical Astrodynamics is an alternative option to ASEN 5050. ASEN 5519: Analytical Astrodynamics will satisfy the same requirements and prerequisites as ASEN 5050.

Advanced Requirements:

Select ANY two 6000 level courses in ASN including, but not limited to, the ASN Electives listed in Appendix 2 and any ASEN 6519 special topics courses offered by faculty in the ASN focus area.

Admission Requirements

Requirements for a Graduate Certificate in Astrodynamics and Satellite Navigation Systems:

- Email aerograd@colorado.edu to be registered as a certificate-seeking student.
- Approval of your ASN course selections.
- Completion, with a grade of B or better, of all required courses.
- Upon completion of your courses, complete the certificate request form and submit it to the Graduate Advisor, aerograd@colorado.edu.

C.3 Certificate in Satellite System Design (SSD)

The certificate recognizes student accomplishments at the graduate level in successfully completing a specialized program of study in Satellite System Design (SSD). It blends courses from the Smead Department of Aerospace Engineering Sciences, Electrical, Computer and Energy Engineering and Engineering Management Departments. The certificate will allow students to develop interdisciplinary skills in the area of satellite design, making them more desirable to future employers.

Certificate Requirements

Track 1: Hands-on (recommended for on campus students)

ASEN 5148 – Spacecraft Design*

ASEN 5018 and 6028 – Graduate Projects (Project must have a satellite or rocket focus)

1 course from elective list

Track 2: Distance Compatible Track

ASEN 5148 – Spacecraft Design*

EMEN 5405 – Fundamentals of System Engineering*

2 courses from elective list (no more than one EMEN course)

To develop cross-disciplinary breadth, students are strongly encouraged, but not required, to choose elective courses outside of their major.

Elective list[1]

ASEN 5010 – Spacecraft Attitude Dynamics and Control*[2]

ASEN 5050 – Space Flight Mechanics*†

ASEN 5053 – Rocket Propulsion

ASEN 5090 – Introduction to Global Navigation Satellite Systems*

ASEN 5335 – Aerospace Environment*

ASEN 5519 – Microavionics [3]

ECEN 5134 – Electromagnetic Radiation and Antennas*

ECEN 5264 – Electromagnetic Absorption, Scattering and Propagation*

ECEN 5517 – Photovoltaic Power Electronics Laboratory

ECEN 5613 – Embedded System Design

ECEN 5623 – Real-Time Embedded Systems

ECEN 5634 – Graduate Microwave and RF Laboratory

ECEN 5692 – Principles of Digital Communications

ECEN 5797 – Introduction to Power Electronics*

ECEN 5813 – Principles of Embedded Software

EMEN 5010 – Introduction to Engineering Management*

EMEN 5030 – Fundamentals of Project Management*

EMEN 5031 – Software Project Management*

EMEN 5405 – Fundamentals of System Engineering*

1: Students are required to meet course prerequisites. Question should be directed to the course instructor.
2: Core ASN certificate courses. Cannot be counted for both certificates.
3: Course enrollment is limited to non-Electrical Engineering students.
* Courses available via distance.
† ASEN 5519: Analytical Astrodynamics is an alternative option to ASEN 5050. ASEN 5519: Analytical Astrodynamics will satisfy the same requirements and prerequisites as ASEN 5050.

Admission Requirements
Requirements for a Graduate Certificate in Satellite System Design:
● Approval of your SSD course selections.
● Email aerograd@colorado.edu to be registered as a certificate-seeking student.
● Completion, with a grade of B or better, of all required courses.
● Upon completion of your courses, complete the certificate request form and submit it to the Graduate Advisor, aerograd@colorado.edu.

Appendix D. List of Approved Certificates

D.1 Interdisciplinary Certificates

Some of the most popular certificate programs include the following.

- Astrodynamics and Satellite Navigation
- Atmospheric & Oceanic Sciences
- Environment, Policy and Society
- Oceanography
- Satellite System Design
- Remote Sensing (Modified for RSESS MS students)

D.2 Professional Certificates

Electrical and Computer Engineering:

- Embedded Systems
- Energy Communication Networks
- Wireless Networks and Technologies
- Radio Frequency (RF) Engineering for Aerospace

Engineering Management:

- Engineering Entrepreneurship
- Engineering Management
- Leadership and Management
- Managing Applied Research in Technology
- Performance Excellence in Technology Management
- Project Management
- Quality Systems for Product and Process Engineering
- Six Sigma Statistical Practitioner
- Technology Ventures & Product Management

Telecommunications:

- Computer and Network Security
- Power Electronics
- Software Engineering

D.3 Certificates Requiring Pre-Approval

Interdisciplinary Certificates

- Behavioral Genetics
- Biotechnology
- Cognitive Science
- Development Studies
- Energy
- Geophysics and Hydrologic Sciences
- Neuroscience and Behavior
- Optical Science and Engineering
- Quantitative Biology
- Science and Technology Policy

Appendix E.Forms

E.1 AES PhD Student Teaching Practicum Worksheet

Name: Advisor:

Current Date: Matriculation Date:

Expected Graduation Date:

PhD Preliminary Exam Date: PhD Comprehensive Exam Date:

Teaching Activities:

AY & Semester	Type of Activity: (Circle one)	Course Name,# or Project Title	Faculty Supervisor	Primary Responsibilities	Status
	Instructor of Record/GPTI Teaching Fellow/Team Teach Teaching /Course Assistant Research Mentor Seminar Coordinator (1yr) Other:_____				Planned Current Completed
	Instructor of Record/GPTI Team-Teaching Teaching/Course Assistant Research Mentor Seminar Coordinator (1yr) Other:_____				Planned Current Completed

Faculty Advisor Signature: _____

Date:_____

E.2 MS Degree Planning Form – ASN Focus

Name: _____ Student ID: _____

Advisor: _____

Focus area: Astrodynamics and Satellite Navigation (ASN)

- 30 or more semester hours total (courses, seminars, thesis)
  - 24 must be 5000 or above
  - 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
  - up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD
- 9-12 semester hours as defined by the student's focus area must be taken in the student's primary focus area and one required course (3 semester hours) must be taken in a second focus area.

ASN focus area requirement: 3 Core Classes

_____ _____ _____

(ASN Core1) (ASN Core 2) (ASN Core 3)

Outside Core: _____

- 3 semester hours of approved math coursework: _____

Circle One:

- MS Thesis, (register for total of 6 credits) or
- Graduate Projects (can be inside or outside the focus area), or
- An approved certificate program

Thesis:

- Represent the equivalent of 6 semester hours of coursework.
- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.
- Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

Courses of interest that Satisfy Math Requirement

_____ _____

Electives (balance of courses up to 30 required total MS hours):

_____ _____

_____ _____

Potential Courses of Interest/Semester Offered:

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.3 MS Degree Planning Form – AUT Focus

Name: _____ Student ID: _____

Advisor: _____

Focus area: Autonomous Systems (AUT)

- 30 or more semester hours total (courses, seminars, thesis)
  - 24 must be 5000 or above
  - 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
  - up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD
- 9-12 semester hours as defined by the student's focus area must be taken in the student's primary focus area and one required course (3 semester hours) must be taken in a second focus area.

AUT focus requirement: 3 Core classes from three different topics

_____	_____	_____
(AUT Core1)	(AUT Core 2)	(AUT Core 3)

Outside Core: _____

- 3 semester hours of approved math coursework: _____

Circle One:

- MS Thesis, or
- Graduate Projects (can be inside or outside the focus area), or
- An approved certificate program, or
- Focus Area approved course sequence (two additional courses from two different areas)

Thesis:

- Represent the equivalent of 6 semester hours of coursework.
- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.
- Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

Courses of interest that Satisfy Math Requirement

_____ _____

Electives (balance of courses up to 30 required total MS hours):

_____ _____

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.4 MS Degree Planning Form – BIO Focus

Name: _____ Student ID: _____

Advisor: _____

Focus area: Bioastronautics (BIO)

- Two focus area core courses: ASEN 5016, ASEN 5158
- One of four specified focus area courses are required: ASEN 5519 Medicine in…, ASEN 6116, ASEN 6519 Human Operation…, ASEN 6519 Extravehicular Activity
- One of three specified second focus area core are required: ASEN 5335 (RSESS), ASEN 5050 (ASN) or ASEN 5053 (FSM); however, students with non-aerospace BS degrees are encouraged to take all

● 30 or more semester hours total (courses, seminars, thesis)

- 24 must be 5000 or above
- 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
- Up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD

● 9 semester hours must be taken in the BIO focus area and 1 required course (3 semester hours) must be taken in a second focus area as defined above.

- Bio focus area requirement: 3 Classes

_____ _____ _____
(BIO Core1) **(BIO Core 2)** **(BIO Core 3)**

- One of 3 required outside Core: _____
(**Outside Core1**)

● 3 semester hours of approved math coursework. _____

Circle One:

- MS Thesis, or
- Graduate Projects (can be inside or outside the focus area), or
- An approved certificate program

Thesis:

- Represent the equivalent of 6 semester hours of coursework.
- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.
- Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

Courses of interest that Satisfy Math Requirement

_____ _____

Electives (balance of courses up to 30 required total MS hours):

_____ _____

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.5 MS Degree Planning Form – FSM Focus

Name: _____ Student ID: _____

Advisor: _____

Focus area: Fluids, Structures, and Materials (FSM)

- Two core courses in primary FSM track
- One core course in the other FSM track

- 30 or more semester hours total (courses, seminars, thesis)
  - 24 must be 5000 or above
  - 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
  - up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD
- 6-12 semester hours as defined by the student's focus area must be taken in the student's primary focus area and one required course (3 semester hours) must be taken in a second focus area.
  - **FSM focus requirement: 2 Core classes in primary track of focus area**

    _____ _____

    (FSM Track 1) (FSM Track 1)
  - **1 Core class in second track:** _____

    (**FSM Track 2**)
- 6 elective credits, at least 3 in primary track:

  _____ _____

- 3 semester hours of approved math coursework: _____

Circle One:

1. MS Thesis, or
2. Graduate Projects (can be inside or outside the focus area), or
3. An approved certificate program, or
4. Focus Area approved course sequence (one additional core course and one additional elective from the FSM courses)

Thesis:

- Represent the equivalent of 6 semester hours of coursework.
- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.
- Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

Courses of interest that Satisfy Math Requirement

_____ _____

Electives (balance of courses up to 30 required total MS hours):

_____ _____

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.6 MS Degree Planning Form – RSESS Focus

Name: _____ Student ID: _____

Advisor: _____

Focus area: Remote Sensing (RSESS)

- four focus area core, one in each primary topic area
- second focus area **core (may also count as primary topic core)**

- 30 or more semester hours total (courses, seminars, thesis)
  - 24 must be 5000 or above
  - 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
  - up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD
- 6-12 semester hours as defined by the student's focus area must be taken in the student's primary focus area and one required course (3 semester hours) must be taken in a second focus area.
  - RSESS focus area requirement: 4 Core Classes, 1 in each primary topic area

_____ _____ _____ _____

(RSESS Topic 1) (RSESS Topic 2) (RSESS Topic 3) (RSESS Topic 4)

- Outside Core (may also fulfill a topic requirement): _____
  (outside core)

- 3 semester hours of approved math coursework _____

Circle One:

1. MS Thesis, or
2. Graduate Projects (can be inside or outside the focus area), or
3. An approved certificate program

Thesis:

- Represent the equivalent of 6 semester hours of coursework.
- Comply in mechanical features with the University of Colorado Graduate School Thesis and Dissertation Specifications.
- Be filed with the Graduate School by posted deadlines for the semester for which the degree is to be conferred.

Courses of interest that Satisfy Math Requirement

_____ _____

Electives (balance of courses up to 30 required total MS hours):

_____ _____

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.7 Professional MS Degree Planning Form

Name: _____ Student ID: _____

Advisor: _____

- 30 or more semester hours total (courses, seminars, thesis)
- 24 must be 5000 or above
- 18 credits of ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
- up to 6 credits can be 4000 level in ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD

▪ 3 semester hours of approved math coursework _____

Courses of interest that Satisfy Math Requirement

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

E.8 PhD Degree Planning Form: All Focus Areas

Name: _____ Student ID: _____

Advisor: _____

Coursework/dissertation requirements:

- 30 or more semester hours course credit (5000 or above)
    - 9 above 6000 (9 credits for RSESS focus)
    - 15 must be in ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class)
    - 6 credits of math from approved list

- 30 hours dissertation credit
- Teaching Practicum
- Preliminary exam (by third or fifth semester) _____
- Comprehensive exam (after coursework completed by fifth or seventh semester/before semester of final defense)_____
- Written Dissertation
- Defense/Final Examination
    - Up to 10 PhD dissertation credits pre-comprehensive exam
    - Up to 10 PhD dissertation credits in semester in which comprehensive exam is passed
    - Remaining PhD dissertation credits post-comprehensive exam, but students must register for a minimum of 5 PhD dissertation credits in each semester following the comprehensive exam through the semester in which final dissertation is successfully defended.

Courses:

15 credits of ASEN coursework

_____	_____	_____	_____
(**ASEN 1**)	(**ASEN 2**)	(**ASEN 3**)	(**ASEN 4**)

_____

(**ASEN 5**)

9 credits of 6000 level or above

_____	_____	_____
(6000 level 1)	**(6000 level 2)**	**(6000 level 3)**

6 semester hours of approved math coursework: _____ _____

Courses of interest that Satisfy Math Requirement

_____ _____

<u>Potential Courses of Interest/Semester Offered:</u>

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____

_____ / _____