Graduate Handbook

Smead Aerospace Engineering Sciences

University of Colorado Boulder

Academic Year 2025–2026

Foreword

The Ann and H. J. Smead Department of Aerospace Engineering Sciences (AES) at the University of Colorado Boulder (CU Boulder) 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 Earth and space 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, designing and building autonomous systems, 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 and undergraduate students, faculty, and research staff work together on a wide range of research topics: aerodynamics and fluid mechanics; aerospace design and systems engineering; astrodynamics and orbital mechanics; atmospheric, oceanic and space sciences; bioastronautics; computational and analytical methods; satellite-based global positioning, navigation, and 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 around CU Boulder. Local major aerospace companies include BAE Systems (formerly Ball Aerospace), Lockheed Martin, Northrop Grumman, Raytheon, and Sierra Space Corporation. There are also countless smaller aerospace companies in the area, both well-established and startup companies. 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). On campus, the AES department collaborates extensively with the Laboratory for Atmospheric and Space Phyics (LASP) and the Cooperative Institute for Research in Environmental Sciences (CIRES), and many of our students find employment at these institutes, both during and after their degree programs.

The Graduate Programs in the AES department prepare students for careers at these and many other institutions through the completion of Masters and PhD degrees. This handbook details the opportunities, requirements, and expectations for graduate studies in AES on the path to completing those degrees. In addition to the rules set forth in this Graduate Handbook, all students are also subject to the rules and provisions required by the Graduate School at CU Boulder. These rules and provisions can be found on the Graduate School website.

Notable Changes in this Handbook Edition

- Update to transfer credit policy for PhD requirements (Section 3.2).
- Update to requirements for the Comprehensive Exam and Advancement to Candidacy (Section 3.5).

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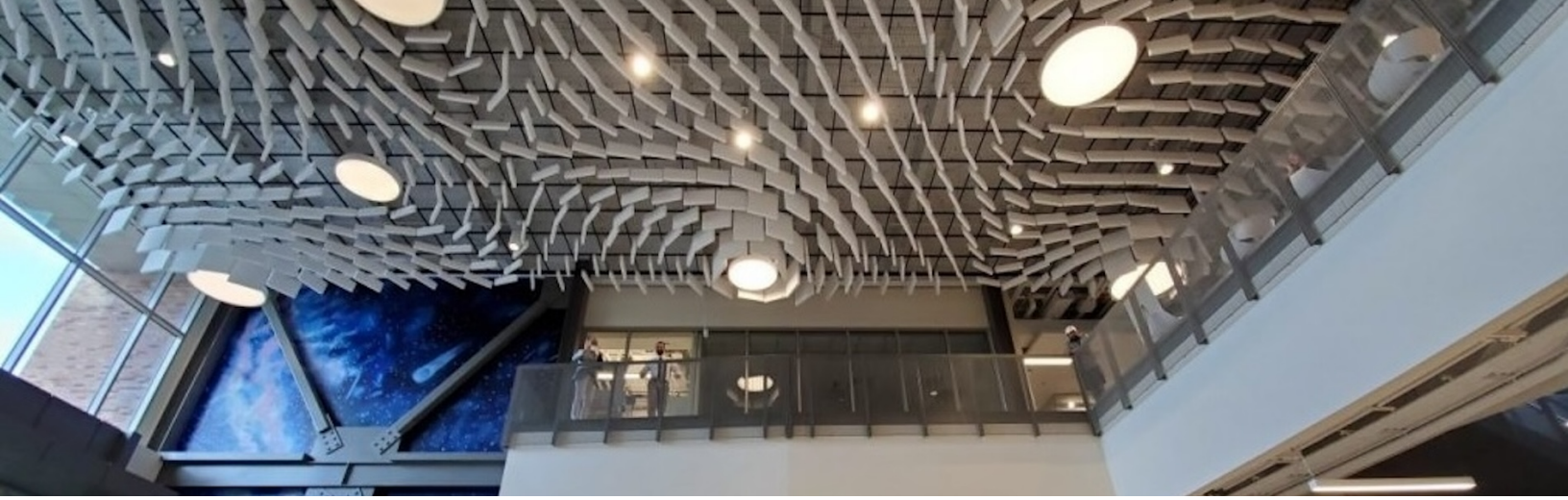


1. Overview

1.1 Focus Areas

The Graduate Program in Aerospace Engineering Sciences (AES) is organized into five *Focus Areas*. These Focus Areas reflect the expertise of our faculty, while providing areas of concentration for students pursuing their MS and PhD degrees. Graduate students in the Traditional MS and PhD programs are admitted into a specific Focus Area, which provides research advising, sets specialized degree requirements, and makes recommendations for coursework both within and outside the department. The five Focus Areas are:

- **Astrodynamics and Satellite Navigation Systems (ASN)**: The ASN Focus Area investigates orbital motion of spacecraft, interplanetary mission design, attitude control, as well as navigation utilizing GNSS and advanced sensors.
- **Autonomous Systems (AUT)**: The AUT 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 (BIA)**: The BIA Focus Area includes the study and support of life in space. It explores how to enable safe and efficient human space exploration.
- **Fluids, Structures and Materials (FSM)**: The FSM Focus Area studies the solid and fluid mechanics behind high-performance aeronautical and aerospace systems.
- **Remote Sensing, Earth and Space Science (RSESS)**: The RSESS Focus Area bridges the gap between science and engineering by studying 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 students in the department with similar research interests and goals.

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. Focus Areas regularly seek out opportunities for synergy with other areas and other departments to avoid duplication and to enhance multidisciplinary research and education.

Specific information on each Focus Area, including their specific curriculum requirements, can be found in Section 4.

Note that the Professional MS program (ProMS) does not require a student to align with a particular focus area. The detailed requirements of the Traditional MS and ProMS programs are outlined in Sections 2.3 and 2.2 respectively.

1.2 Key Contacts

Graduate Advisors:

The graduate advisors (Graduate Program Advisors or GPAs) are students' first point of contact. Intimately familiar with the policies of the graduate program at the department, college, and university level, graduate advisors assist in the resolution of administrative processes and assist student, faculty, and staff in all matters related to graduate studies. Graduate advisors enroll students in dissertation, thesis, and independent study credit hours. They are also able to revise degree plans and confirm fulfillment of degree requirements.

Graduate Program Manager

- **Nicole Simmons**
  Nicole.M.Simmons@colorado.edu
- The GPM supervises the Graduate Program advising team and directs the graduate program in partnership with the Graduate Chair.

Graduate Program Advising Team

- **Maureen Craig**: BAM and Certificate Programs Graduate Program Lead Specialist
  Maureen.Craig@colorado.edu
- **Carmody Lee**: MS and ProMS Graduate Program Specialist
  carmody.lee@colorado.edu
- **Lydia Pinkham**: PhD Graduate Program Specialist
  Lydia.Pinkham@colorado.edu

Graduate Chair

- **Professor Robert Marshall**
  aesgradchair@colorado.edu
- The Associate Chair for Graduate Studies, or simply *Graduate Chair*, is the primary faculty member directing the graduate program.

Department Chair

- **Professor Hanspeter Schaub**
  aeschair@colorado.edu
- The Department Chair oversees the entire department and all its programs.

1.3 Academic Standards and Student Expectations

Graduate students throughout the University are required to maintain at least a B (3.00) average in all work attempted while enrolled in the Graduate School. For both the Master's degree and PhD, a course grade below B- is unsatisfactory and will not be counted toward fulfilling the minimum requirements for the degree.

Please visit CU Boulder's Graduate School website and review their Policies and Procedures for details about grading policy, registration and enrollment, maintaining academic standards, and policies relating to discrimination and harassment, classroom behavior, and honor code.

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 re-admitted 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.

2. Master of Science Degree

The Master of Science (MS) in Aerospace Engineering Sciences (AES) is an advanced degree that aims to provide students further specialization after their Bachelor of Science degree. The MS degree in Aerospace Engineering Sciences can be obtained via two paths:

- In the **Traditional MS** program, the course of study is aligned with a Focus Area. This degree program requires completion of Focus Area-specific curricular requirements and one of the options detailed in Section 2.3.
- The **Professional MS (ProMS)** program offers a more flexible, course-based curriculum, not aligned with a specific Focus Area curriculum. The ProMS was designed for students currently working while completing their Masters degree part-time, but the program is open to all admitted students.

In addition, the MS program in AES includes the following pathways:

- The **Bachelors and Accelerated Masters (BAM) program** is open to current AES undergraduate students who meet certain requirements (Section 2.4). BAM students must choose from either the traditional MS or ProMS options above.
- The Dual Graduate Degree in Aerospace Engineering and Engineering Management allows students to complete both an AES Master's Degree with a Masters in Engineering Management, preparing students for future careers in engineering leadership.

The next sections detail the requirements that are common to both the Traditional MS and Professional MS Programs, including the dual MS in Aerospace Engineering and Engineering Management.

2.1 Common Requirements for all MS Degrees

The following requirements must be met for all MS degrees, including the Tranditional MS, ProMS, and BAM program:

1. **Total course credits:** A total of 30 course credit hours is required (equivalent to 10 classes[1] for most Focus Areas):
   - 24 credit hours or more must be completed at the 5000 level or above.
     - Up to 6 credit hours can be taken at the 4000 level in related engineering, math, and science departments.[2]
     - ASEN courses 4000 and below do not fulfill degree requirements.
   - 18 credit hours or more in ASEN courses.
     - EMEN 5405: Fundamentals of Systems Engineering counts towards these ASEN course credits.
2. **Time Limit:** All degree requirements must be completed within four years. Two years is the average time of completion in our department.

Important Notes:

- Courses taken in non-related departments[3] do not fulfill degree requirements.
- Seminar credit hours (including seminar credit hours earned in other disciplines) do not count toward the MS degree.

2.2 Professional MS Program Requirements

The Professional Master's degree (ProMS) in Aerospace Engineering Sciences is designed to give students the technical knowledge and professional skills to be successful in careers related to aerospace engineering. A ProMS offers students flexibility by not requiring them to follow Focus Area-specific curricular requirements.

There are no additional requirements for the ProMS degree beyond those listed in Section 2.1 above.

ProMS students are not eligible for research or teaching assistantships; however, hourly positions are allowed (course, research, or administrative support). Teaching Facilitator (TF) positions are considered hourly.

2.3 Traditional MS Program Requirements

In the Traditional MS program, students choose one of the Focus Areas for specialization and they must complete a series of courses designed by the Focus Area to provide the fundamentals of the field. Students are also required to complete one of these options:

1. Masters (MS) thesis.
2. Graduate Projects I and II (ASEN 5018 and 6028).
3. Required courses leading to an approved certificate.
4. Course-based MS requirements determined by student's Focus Area (AUT or FSM only).

[1] Note: Most of our graduate courses are 3 credit hours.

[2] Allowable departments are: APPM, AREN, ASTR, ATLS, ATOC, BCHM, BIEN, BMEN, CHEM, CHEN, CSCI, CVEN, CYBR, DTSC, ECEN, ENEN, ENVD, EVEN, GEOL, IPHY, MATH, MCDB, MCEN, MSEN, PHYS, ROBO, STAT.

[3] Non-related departments are those not listed in the footnote above.

5. Completion of the Dual Aerospace Engineering and Engineering Management MS degree.

2.3.1 MS Thesis Option

The MS thesis must consist of original and independent research conducted by the graduate student under the supervision of a faculty advisor and must be related to the Focus Area. Requirements include:

- Complete 6 credit hours of ASEN 6950 (MS Thesis).
- Complete a Master's dissertation that complies with the Graduate School's format requirements and specifications.
- Complete a final examination (defense). The examination committee for the MS thesis consists of three regular graduate faculty members, two of which must be in the Aerospace Engineering Sciences department.
- Successfully defend and submit the thesis by the graduation semester's deadlines. Refer to the Graduate School's page for details.
- For additional information, please see the Graduate School Rules.

2.3.2 Graduate Projects I and II

Graduate Projects (ASEN 5018/6028) is a two-semester course sequence designed to expose MS and PhD students to engineering project work, project management, systems engineering, and subsystem-level design and testing. Students work in teams of 5 to 20 under the guidance of a faculty project advisor. Projects are related to one or more of the five Focus Areas; however, students may select any project regardless of their declared Focus Area. Additional information on the projects available for the upcoming semester can be found in our Graduate Projects page.

Note: Graduate Projects may be taken as a distance course only with approval of the project advisor.

2.3.3 Approved Certificate

Graduate certificates allow students to explore an interdisciplinary area while pursuing a master's or doctoral degree in a specific department. For the certificate, students often take classes outside their Focus Area or department, or engage in research work for certificate programs with research requirements. After completing the required courses, students receive a certificate in the interdisciplinary field of choice. For a list of approved certificates, requirements, and more details, please see Section 5.

Note: For all AES certificates, students must obtain grades of B or higher in all courses towards certificate completion to be awarded the certificate. For certificates in other departments, including Engineering Management, students are referred to the graduate program advisors or coordinators in the department managing the certificate. The complete list of certificates offered at CU Boulder is available on the Graduate School website; however, only those listed in Section 5 in this handbook are approved to satisfy the MS degree option.

2.3.4 Focus Area-Specific Coursework

The Autonomous Systems (AUT) and Fluids, Structures, and Materials (FSM) Focus Areas offer the option to complete the Traditional MS degree simply by completing additional coursework. These courses must represent at least an additional six credit hours to complete the MS in that Focus Area. The details for each Focus Area can be found in Section 4.

2.3.5 Dual Aerospace Engineering and Engineering Management MS Degree

The dual MS degree in Aerospace Engineering and Engineering Management enables future engineering leaders with the technical knowledge and skills that come with the engineering degree, and the leadership and management skills from the Engineering Management program. Please review the Dual Aerospace Engineering and Engineering Management MS degree page for more details or contact the ASEN MS Graduate Program Advisor (see Section 1.2), or contact Kendra Thibeault, the EMEN Graduate Coordinator. *Note: BAM students are not eligible for this dual degree option.*

2.4 Bachelor's–Accelerated Master's (BAM) Program

The Bachelor's–Accelerated Master's (BAM) degree programs offer currently enrolled CU Boulder undergraduate students the opportunity to complete their bachelor's and master's degrees in a shorter period of time. Students receive the bachelor's degree first, but begin taking graduate coursework as undergraduates (during the senior year). Because some coursework may be counted towards both the bachelor's and the master's degrees, students may earn a master's degree in less time and at a lower cost than a stand-alone master's degree program. In addition, staying at CU Boulder to pursue the BAM program allows students to continue working with their established faculty mentors.

Note: There are two different BAM program options available to aerospace students. Students can choose between an Master of Science in Aerospace Engineering Sciences or a Professional Master of Engineering in Engineering Management. Information on the aerospace BAM program is provided below. For details on the Engineering Management BAM program, visit the Lockheed Martin Engineering Management Program website. Note that only one Master's degree option can be selected.

2.4.1 Admissions Requirements

In order to gain admission to the BAM program, you must meet the following criteria:

- A minimum 3.50 cumulative GPA overall
- A minimum 3.50 GPA in ASEN coursework
  - ASEN coursework is any ASEN 2000-level course and above (excluding ASEN 3036 & ASEN 3046).

2.4.2 Program Requirements

Students may take up to 12 credit hours while in the undergraduate program which can later be used toward the Master's degree. However, only six credit hours may be double counted toward the bachelor's degree and the master's degree. Students must apply to graduate with the bachelor's degree, and apply to continue with the master's degree, early in the semester in which the undergraduate requirements will be completed.

Note: Courses that were applied to both the undergraduate and MS degrees **cannot** be applied to a PhD degree. Courses that were only applied to the MS can be applied to a PhD degree. Students should refer to their BAM Supplement Form to determine which courses were applied to the undergraduate and MS degrees.

2.4.3 Applying to the BAM Program

Students apply to the BAM program at the end of their Junior year, prior to enrolling in Senior Projects 1 (ASEN 4018). Application dates and deadlines are located on the BAM website.

For enrollment prerequisites, refer to the catalog pages. In preparation to apply, please visit these resources:

- The Graduate School website provides information for prospective and current graduate students.
- The Graduate School's Policies and Procedures provide detailed information on credit enrollment limits, academic probation, credit transfer rules, and other subjects.

Eligible students may apply for the BAM program by completing the **BAM Intent Form**. Visit the Registrar's Office BAM page for more information.

2.4.4 Resources for Students in the BAM Program

- It is expected that all BAM and graduate students will be fully familiarized with the content of this Graduate Handbook and the MS degree and Focus Area requirements.
- BAM students can choose from any of the MS degree options, with the exception of the dual degree MS in Aerospace Engineering and Engineering Management.
- Recommended graduate courses that can be taken before being declared a graduate student can be found on our BAM Program Page.
- More information about BAM programs, policies, and forms may be found on the Registrar's Office website as well as the Graduate School's website.

2.5 Transfer of Credits for all MS Students

Master's degree students can transfer a limited number of course credits from another institution to be applied to their MS degree program in AES. Transfer credit is defined as any credit earned at another accredited institution, credits earned on another campus of the CU system, or credits earned as a non-degree student within the CU system.

- Students can request a Transfer of Credit after completing six credit hours as a degree-seeking student at CU Boulder.
- Up to nine credit hours of graduate level coursework may be accepted for degree requirements.

Please see the Graduate School's Policies and Procedures page on Transfer Credits for more requirements, limitations, and exceptions regarding transfer credit.

To request a credit transfer, complete the Transfer of Credit Request by following the instructions provided by the Graduate School. The form will be routed through the GPA, your faculty advisor, the Associate Chair for Graduate Studies, and the Graduate School.

To apply transfer credits towards specific curricular requirements in AES, students must submit a academic petition for each request *after* the general transfer credit has been approved by the Graduate School.

2.6 Transitioning from the MS to PhD Program

MS students in Smead AES may wish to pursue research at the doctoral level and completion of the PhD degree. Research towards the PhD degree is guided by a faculty advisor in the area of their research expertise. Current MS students interested in completing a PhD must secure the commitment of a faculty advisor willing to support them during their PhD career.

Before students can officially transition from the MS program to the PhD program, the following steps must occur:

1. The student must still be actively enrolled as a graduate student at CU Boulder. *If the student has already graduated (had a degree officially conferred), the student will need to submit a regular graduate application to enter the PhD program.*
2. As mentioned above, the student must have an AES faculty member (Assistant, Associate, or Full Professor) who has agreed to serve as the student's PhD advisor.
3. Once the student has a confirmed faculty advisor, *the advisor must email the Graduate Program Manager and the Associate Chair for Graduate studies (Section 1.2) confirming acceptance of the student.* Further instructions will be sent to the advisor and student. **Note: no action will be taken to transition the student to the PhD program without a confirmed faculty advisor.**

Additional Notes:

- Courses taken as an MS student in Smead AES will also count towards the PhD, with the exception of MS Thesis credits. Students may reach out to the PhD Graduate Advisor with any questions about requirements.
- For BAM students who transition to the PhD program, courses that were applied towards both the undergraduate and MS degrees **cannot** be applied to the PhD. Courses that were applied only to the MS can be applied to the PhD. Students should reference their BAM Supplement Form to determine which courses were applied to the undergraduate and MS degrees.
- Students who enter the PhD program will adhere to the handbook from the year in which they enter the PhD program, not the handbook from when they originally entered the MS program.

3. Ph.D. Degree

The Doctor of Philosophy (PhD) in Aerospace Engineering Sciences (AES) is an advanced degree indicative of the highest level of academic achievement in a given discipline. It is awarded following a course of graduate study (i.e. coursework) and original research that contributes new knowledge or developments in the specialized subfield of Aerospace Engineering and/or related sciences.

The PhD degree is primarily a research-oriented academic achievement. The degree itself is an indicator of the student's capability of conducting, documenting, and defending original research. The coursework requirements for the PhD primarily support the PhD research by providing the foundational knowledge and skills necessary to complete the research.

This chapter outlines the requirements, expectations, timeline, and milestones for the PhD program in AES.

3.1 Faculty Advisor and Student Expectations

The PhD degree is a unique education and training experience involving a long-term commitment to research and a unique relationship with a PhD faculty advisor. This section outlines expectations for student performance, advisor-advisee agreements, and the expected completion timeline for the PhD degree.

3.1.1 PhD Student Statuses

PhD students have three statuses within the department and the university:

- **Advisee**: The advisee status refers to the research advising relationship between a PhD student and their AES Faculty Advisor. The advising relationship is *at-will* and may be terminated by the student or Faculty Advisor at any time.
- **Employee** (i.e. employment as a GRA, GTA, or GPTI): The employee status refers to a student's employment to perform research or teaching duties. The terms and conditions associated with a Graduate Student Appointment are defined in the employment offer letter. This employment is *at-will* and may be terminated by the employee (student) or employer (supervisor) at any time. Further details of different appointment types are described in Section 6 below.
- **Student**: The student status refers to status as a PhD student enrolled through the Graduate School at CU Boulder, and is not controlled by the AES department. For more information on rules and regulations governing student status please see the Graduate School Policies and Procedures.

3.1.2 Faculty Expectations

Students may expect certain standards from their professors, faculty advisors, and supervisors. It is the supervisor's responsibility to clarify their policies regarding time off, work hours, publication authorship, funding, and more; it is the student's responsibility to seek out this information. Professors guide students in their research, teaching, and professional development, and assist them with post-graduation job placement. They provide students with opportunities for industry or laboratory internships and encourage their attendance at professional conferences. Professors provide students with an annual evaluation of their progress in meeting their degree requirements and in their research. In the case of a Graduate Research Assistant (GRA) appointment, financial support is guaranteed so long as the student is making acceptable progress in their funded research work (as determined by their advisor) and funding continues to be available.

3.1.3 Advisor/Advisee Agreement

An Advisor-Advisee Agreement must be completed in the first semester a student enters the PhD program. For students entering in fall semester the agreement must be completed prior to October 30; for students entering in spring semester the agreement must be completed prior to March 31.

The purpose of the Advisor-Advisee Agreement is to assist PhD students and their Faculty Advisors in navigating conversations around the PhD process and student progress. This document identifies common points of discussion in order to facilitate a dialogue between the student and advisor. The objective is to develop a shared understanding of roles, responsibilities, expectations, and anticipated workload that will help achieve the shared goals and set expectations from the beginning of a student's PhD career.

Process for completing the Advisor-Advisee Agreement:

- Students and Faculty Advisors schedule a time to review and discuss the agreement after the start of the semester, ideally in late September or early October.
- After the agreement has been discussed, the Advisor-Advisee Agreement Form is submitted by the deadline for the semester in which the student entered the program.
  - Note: the agreement form will provide space for documenting tailored expectations that are discussed and agreed upon.
  - Note: faculty may opt to use their own agreement form already in place for a research group and/or lab. In this case, faculty are responsible for retaining these forms.
- The Agreement Form can be found on the department's Forms for Graduate Students page. The faculty advisor will initiate the form and fill out the required fields, then the form will be sent to the student for review and signature. Both student and advisor will receive copies upon completion.

3.1.4 PhD Student Annual Evaluations

PhD students are subject to academic requirements and standards for adequate academic progress specified by both the Graduate School and their graduate program. Students are responsible for familiarizing themselves with the policies and requirements of the Graduate School and their graduate program. Graduate School campus-wide requirements and program-specific requirements are tracked in different ways; please reference the Graduate School Rules and Graduate School Guidelines for Student Academic Progress and Success and Procedures for Dismissal for more details on campus-wide requirements and tracking. Smead AES specific requirements are outlined in Section 3.2.

Evaluations are completed annually in October, beginning in the student's second academic year in the program. The annual evaluation process consists of the following steps:

- Faculty Advisors will receive a link to the evaluation form via email for each of their students.
- The student and advisor will schedule a meeting to discuss the evaluation during the month of October.
- After the discussion, the Faculty Advisor signs the evaluation form, and the form is sent to the student for signature. The completed form will be sent to all parties and stored in the student's record.

3.1.5 Disagreements (non-grade related)

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

Students may elect to pursue resolution processes outside of the department at any point. Please consult CU Boulder's Graduate School Policies and Procedures for information about student grievance policies and procedures.

3.1.6 PhD Degree Completion Time Limit

Doctoral degree students are expected to complete all degree requirements within six years from the semester in which they are admitted and begin course work in the doctoral program. Students who fail to complete the degree in this six-year period may be dismissed from their program with the

concurrence of the faculty advisor and/or appropriate departmental personnel. To continue in the program, the student must file a petition for an extension of the time limit with the Dean of the Graduate School. Such petitions must be endorsed by the student's faculty advisor and/or other appropriate departmental personnel and may be granted for up to one year.

3.2 PhD Program Requirements

Completion of the PhD degree requires the successful completion of coursework requirements, examinations, a doctoral practicum activity, doctoral research, and a final dissertation defense.

3.2.1 Coursework Requirements

1. **Total course credits:** PhD students must complete a total of 30 course credit hours numbered 5000 or above.
   (a) **Advanced courses:** At least 9 credits shall be taken as *advanced graduate courses*, defined as courses that have a graduate level prerequisite. All 6000-level courses in ASEN meet this requirement, but advanced graduate courses from other departments or universities may also count. The student must demonstrate that the course has a graduate level prerequisite, or otherwise covers material at an advanced graduate level.
   (b) **Minimum ASEN courses:** At least 15 credit hours must be in ASEN (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class).
   (c) **Note:** Courses taken in related departments may count towards the overall requirement of 30 course credits. [1]
2. **Minimum GPA:** Per department requirements, a minimum cumulative GPA of 3.25 must be maintained. 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 faculty advisor, will be subject to suspension from the Graduate School at the advice of the department. The final decision on suspension will be made by the Dean of the Graduate School.
3. **Transfer credits:** Up to 21 credit hours of graduate-level courses can be transferred to meet PhD course requirements. See the Graduate School Policies and Procedures for more details.
   (a) Note: PhD students who are transferring in graduate coursework from a previous institution may petition for up to 6 credits of transferred coursework to count towards ASEN credits (i.e. towards requirement 1(b) above). Students will be required to show equivalency between the transferred course and an established ASEN course for the petition to be approved. Students may only petition this requirement with a course that is approved by the Graduate School, and can only petition the number of credits granted by the Graduate School on the transfer credit request form. Students should contact the PhD GPA with questions.
4. **CU Masters credit:** All credit hours earned from an MS program taken at the University of Colorado Boulder can be applied toward a PhD (with the exception of MS thesis credit hours and any credits applied towards an undergraduate degree).
5. **Dissertation credit hours:** At least 30 PhD dissertation credit hours must be completed. 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

[1] Related departments are: APPM, AREN, ASTR, ATLS, ATOC, BCHM, BIEN, BMEN, CHEM, CHEN, CSCI, CVEN, CYBR, DTSC, ECEN, ENEN, ENVD, EVEN, GEOL, IPHY, MATH, MCDB, MCEN, MSEN, PHYS, ROBO, STAT.

extending through the semester in which the dissertation is successfully defended (Doctoral Final Examination). See the Graduate School Policies and Procedures for more details.

6. **Focus Area Curricular Requirements:** See Section 4 for more information.

3.2.2 PhD Examinations Summary

In addition to these course requirements, students are required to pass a series of examinations:

1. Students must pass the **Preliminary Exam** by their 5th semester as a CU Boulder PhD student, although most students take the exam in their 3rd semester. If a student enters the PhD program with a master's degree in Aerospace Engineering, their Faculty Advisor can require the exam be taken by their 3rd semester. The Preliminary Exam is administered once per year, during the first 2–3 weeks of the Fall semester.
2. Students must pass a **Comprehensive Exam** in order to advance to PhD Candidacy. The timeline for completion of the Comprehensive Exam is at the discretion of the student's faculty advisor, but is typically taken by the 3rd or 4th year of the PhD program, 1–2 years before the expected defense date. Students should consult with their advisor after completing the Preliminary Exam to discuss the expectation for research progress before scheduling the Comprehensive Exam.
3. **Doctoral Final Exam:** Finally, students must complete a PhD dissertation and successfully defend the dissertation in a Doctoral Final Examination. The Graduate School also requires the accumulation of PhD dissertation credit hours within the maximum 6-year program length to complete the PhD. See the Graduate School Policies and Procedures for more details.

3.3 Doctoral Practicum

3.3.1 Objectives

The Doctoral Practicum (DP) is a required element of the PhD program in Smead Aerospace that complements the primary research and academic experiences which are core to the completion of a PhD degree. The objective of the DP is to provide students with an experience to use their advanced education to teach, mentor, and serve as role models. The emphasis of the practicum is on using technical skills, education, and insights in service to others. The expectation is that this activity will help students grow confidence and skills as leaders. The process is formative and students are responsible for articulating how their chosen practicum will be structured toward achieving the following goals:

1. Provide meaningful educational or societal benefit.
2. Provide intrinsic value to the student's professional or personal development.
3. Leverage the research and/or educational skills developed in the PhD program towards the two goals above, i.e. societal benefit and personal development.

3.3.2 Examples

Examples of acceptable DP activities include, but are not limited to:

- Participation in the Graduate Part Time Instructorship (GPTI) or iTA program for one semester
- Serving as a Graduate Teaching Assistant (GTA) or Teaching Facilitator (TF) for one semester
- Team teaching a course with an AES faculty member
- Serving on the MS Application Review Committee
- Participating in the PhD applicant mentor program

- Significant service activities, such as serving in student organizations, or the Inclusive Culture Committee
- Mentor for undergraduate or MS student research such as the Discovery Learning Apprentice (DLA), SPUR, or SMART programs
- Coordinator for Focus Area Seminar classes
- Industry or governmental internship that develops and applies professional skills outside the student's core research area (i.e., application of technical skills to development of policy, regulations, or societal need)
- Entrepreneurship activities that address societal needs or support underserved populations

3.3.3 Process

It is expected that the DP will be formative and require intellectual effort. Acknowledging that this can occur over varied timescales, the **estimated commitment should meet or exceed a minimum of 40 total hours of effort**. Larger investments of time are likely and acceptable but are not required.

The following process outlines how the student is to structure their DP to demonstrate they have satisfied the DP goals. Much like the research plan and course selection, the development of a DP plan should be a collaborative effort between the student and their faculty advisor.

- **Step 1:** Students should discuss their proposed DP activity with their faculty advisor prior to the completion of the Preliminary Exam. The advisor should work with the student to ensure they both have consistent expectations of the timing, level of effort, and means by which the three DP goals are satisfied.
- **Step 2:** The Doctoral Practicum Proposal Form is typically submitted prior to Comprehensive Exams. The proposal will consist of a form summarizing the DP plan and how the chosen activity addresses each of the DP goals (each requiring a 1-paragraph description). The DP proposal must be approved by the student's faculty advisor, Focus Area lead, and Associate Chair for Graduate Studies. If rejected, the student should revise and resubmit the DP plan for approval based on feedback.
- **Step 3:** Prior to the PhD defense, the student shall submit the Doctoral Practicum Completion Form. Together with this form, students must submit a 1-page letter specifically addressing the doctoral practicum requirements and goals, and reflecting on the doctoral practicum activities and how those activities met the goals outlined in the Doctoral Practicum Proposal.

3.4 Preliminary Exam

The Preliminary Exam evaluates each student's academic qualifications and competency for entrance into the PhD program. The goal of the Preliminary Exam is to ensure that all students continuing in the program have the technical and communications skills required for successful completion of the doctorate. This exam covers academic coursework, basic research skills, and oral and written communication skills. After passing the Preliminary Exam, a student is considered a PhD pre-candidate.

3.4.1 Preparation for the Preliminary Exam

A student is not required to have a faculty advisor to take the preliminary examination. However, typically the student's faculty advisor serves as the chair of the preliminary exam committee, and provides the literature review topic for the exam. If a student does not have a faculty advisor at the time

of the preliminary exam, they must work with the Graduate Chair and Graduate Program Manager to identify another faculty member to serve as the Preliminary Exam committee chair.

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 Doctoral Practicum (see Section 3.3). It is recommended that students work with their faculty advisor *before* their first year of classes to identify the in-focus and out-of-focus classes to be used in the preliminary exam, and ensure those classes are completed in the first year of studies.

The Preliminary Exam is administered on an annual basis at the beginning of the fall semester (i.e. typically between August 15 and September 15). The exam must be taken by students by their 5th semester as a CU Boulder PhD student, although most students take the exam in their 3rd semester[2]. If a student enters the PhD program with a master's degree in Aerospace Engineering, their faculty advisor can require the exam be taken by their 3rd semester.

3.4.2 Exam Committee

The Preliminary Exam Committee consists of three ASEN Regular Graduate Faculty members (as defined by the Graduate School). Except in very unusual circumstances (i.e., the student does not currently have a PhD advisor), the student's PhD advisor normally serves as the committee chair. The remaining two committee members will be appointed by the Focus Area Leads based on the selection of exam subjects by the student. After the assignment of the Preliminary Exam Committee, students are encouraged to reach out to each of the faculty members to discuss expectations for the exam.

If the student is co-advised or has multiple PhD advisors, then only one may serve as a voting member on the Preliminary Exam committee. Both advisors may participate in the exam, but only one is considered a member of the committee and will sign the Preliminary Examination Report.

3.4.3 Exam Format

The Preliminary Exam is an oral exam conducted before a committee of three ASEN Regular Graduate Faculty members that focuses on both research preparation and fundamental knowledge in key subject areas.

The Preliminary Exam consists of three components:

1. A research presentation, composed of a literature review, oral presentation, and oral examination.
2. An In-Focus-Area fundamental subject examination.
3. An Out-of-Focus-Area fundamental subject examination.

The literature review (#1 above) is intended to test the student's preparation for their ongoing graduate research activities, setting the trajectory of their work and even potentially serving as the starting foundation for the introduction in their final dissertation. The topic of the literature review shall be determined by the student and their primary research advisor and will be assigned to the student by July 1 prior to the exam period. The literature review can focus on a detailed review of a single paper, or a broader review of multiple works relevant to the student's main research focus.

The literature review portion of the exam includes:

[2] For students starting the PhD program in the spring semester, the preliminary exam time clock begins the fall semester after the student enters the program.

- a written literature review, not to exceed two pages of text with an additional page allotted for references;
- a 5–10 minute oral presentation by the student, not to exceed five prepared slides summarizing the literature surveyed (not including title or reference slides); and
- a question-and-answer period with the committee, discussing the written review, presentation, or both.

The student must email the two-page literature review to the preliminary exam committee members **two weeks prior to the first day of the preliminary exam period.** The student's presentation slides are not due until the time of the exam.

The two fundamental subject areas (#2 and #3 above) will be selected by the student. One subject must be selected from topics within the student's primary Focus Area; the other subject area must be selected from outside of the student's primary Focus Area. Section 7.1 lists the allowable courses for the Preliminary Exam in each Focus Area. If a course is listed under multiple Focus Areas including the student's primary Focus Area, it cannot be used as an out-of-Focus Area subject.

The Preliminary Examination will begin with the student's oral presentation summarizing the literature surveyed, highlighting the key conclusions of the work, and potential directions for future research. Following the student's presentation, the committee members will ask questions of the student about their literature review (both the written review and the oral presentation). This examination and discussion will be led by the student's primary research advisor, but the remaining two committee members are also expected to participate.

The questions and discussion in the two Fundamental Subject exams will be led by the remaining two committee members (i.e. not the student's advisor); however, other committee members are permitted to actively participate in cross-examination and discussion. This portion of the exam is closed to all outside resources (e.g. crib sheets, notes, textbooks, etc.), but the students will be provided a white board and dry erase markers for working out problems in front of the committee. During the exam, students are encouraged to vocalize all steps and thoughts associated with working through each question/problem. By verbally describing their thought process and visually annotating the details on the white board, students will provide the committee a better understanding of their knowledge and problem solving skills.

Each of the oral exam components is expected to take approximately 30 minutes, with a total exam duration of up to two hours (allowing for an additional 30 minutes of discussion and/or deliberation by the committee). The exam will be scheduled by the Graduate Advising Team, and will take place during a first 2–3 weeks of the Fall semester. Note: students may be asked to accommodate the committee availability by missing classes or other commitments during this two week period, but all exams will be administered during normal business hours (i.e. between 8 am and 5 pm, Monday to Friday).

3.4.4 Subject Matter

Section 7.1 lists the Preliminary Exam courses allowed by each Focus Area. While students are not required to have completed these courses for academic credit in order to use them in the Preliminary Exam, they are strongly encouraged to take them during their first year of study to prepare for the Preliminary Exam. **Note: choosing not to take these courses does not provide grounds for a petition for an outside topic.** The topics outlined in each of these course syllabi (accessible on the Smead Aerospace Department website) define the content that may be covered during the Preliminary Exam.

In general, questions may include Master's 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.

3.4.5 Grading and Outcomes

After the exam is complete, the committee members will confer to determine the exam outcome. Possible outcomes for the exam are Pass, Delayed Decision, or Fail. This overall outcome depends on the results of each exam component.

Students are not permitted to discuss their preliminary examination with anyone until after all preliminary examinations are completed. Failure to abide by this rule is an Honor Code violation.

For each of the three components (literature review, in-focus-area exam, and out-of-focus-area exam), each committee member will provide a grade of either Excellent, Satisfactory, Unsatisfactory.

- If a single component receives one grade of Unsatisfactory, the outcome for *that component* is a Delayed Decision. The student must satisfy the Delayed Decision conditions provided by the examination committee no later than the first two weeks of the spring semester following the initial exam. If the conditions are not met favorably by the student, then the outcome becomes a Fail and a student must retake that exam component the following year.
- If a single component receives two grades of Unsatisfactory, the outcome for *that component* is a Fail. The student must retake that component the next year, and the student has the option of switching to a different subject for the retake.
- If the outcome for two or more components is a Fail, the overall outcome of the preliminary exam is a Fail. If this is the first Fail, the student may retake the entire exam the next year. The student has the option of switching subjects for the retake. If the third topic received a pass, it is at the committee's discretion whether or not the student must retake the third topic, and this decision must be documented in the initial Preliminary Examination Report.

3.5 The Comprehensive Exam and Admission to Candidacy

Advancement to PhD Candidate status occurs with the successful completion of the Comprehensive Exam. The Comprehensive Exam is designed to test a student's readiness for their PhD research, including (but not limited to) the demonstration of their capability to conduct research; the formulation of a research plan; the demonstration of technical writing and oral presentation skills; and the mastery of the technical background necessary for the PhD research. The exam consists of a written research proposal, an oral presentation, and an oral defense of the research plan; details of these exam components are described below.

3.5.1 Requirements

The Comprehensive Exam is scheduled in consultation with the student's faculty advisor. The faculty advisor may have concrete expectations that a student must achieve to demonstrate readiness for the Comprehensive Exam, but due to the nature of research and the variation in research projects, there are no uniform expectations. Students are encouraged to discuss their expectations for Comprehensive Exam readiness shortly after completing the preliminary exam.

The following requirements must be must met before undertaking the Comprehensive Exam:

- Completion of the Preliminary Exam.
- The student must be at full time status the semester taking the comprehensive examination.
- A student shall have a GPA of 3.25 for all graduate ASEN or CU coursework.
- The Comprehensive Examination must be taken at least one semester before the Final Exam (i.e. dissertation defense).

Note that students do not need to have completed all PhD coursework in order to take the Comprehensive Exam. In this case, students need to list any remaining coursework on the Candidacy Application, and have passed the Comprehensive Exam, in order to advance to candidacy.

3.5.2 Committee Composition

The Comprehensive Exam committee is typically the same as the final exam / PhD defense committee; students should therefore consider their defense committee when requesting faculty members to join their Comprehensive Exam committee. Changes to the committee can be made between the Comprehensive Exam and defense, if necessary, with faculty advisor approval.

Students should discuss potential committee members with their faculty advisor. The faculty advisor will be best positioned to assess the appropriateness of each committee member based on their expertise.

The committee is composed of at least five, but no more than six, individuals. These members are considered the *voting members* of the committee.

The committee composition must meet the following stipulations:

- The chair of the committee must have a regular Graduate Faculty Appointment.
- Three of the members must be regular CU Boulder Graduate Faculty members from the AES department.
- One committee member must be from a department or institution external to AES.
- The fifth (and optional sixth) committee member(s) may be either internal or external to AES.

External committee members must either have a regular Graduate Faculty appointment in a different department at CU Boulder or hold a special Graduate Faculty appointment (GFA) with approval to serve as an external member. Consult with your Graduate Program Advisor at least one month prior to the comprehensive or thesis exam in order to request a GFA for an external committee member.

Professors from other departments who hold courtesy appointments in AES can be included as either internal or external members.

The student's faculty advisor typically serves as the Committee Chair, unless a conflict of interest or other extenuating circumstances have been identified.

3.5.3 Forms

- The Comprehensive Examination form must be submitted at minimum **2 weeks prior to the examination date.** Please review the Graduate School's informational guide for completing this electronic form prior to completing it.
  - Note: students must email their Graduate Program Advisor once the exam is complete to initiate the committee's signature process.
- The Candidacy Application must be submitted **within 2 weeks of completing the Comprehensive Exam.** Please review the Graduate School's informational guide for completing this

electronic form prior to completing it.

3.5.4 Written Research Proposal

No later than **one week prior to the exam**, the student must provide committee members electronic copies of their written proposal.

The written element of the Comprehensive Exam consists of a research proposal that demonstrates the student's capacity for scholarly work in their chosen topic, lays out a proposed plan for the remaining research activities, and includes a timeline for the proposed research tasks. The document is typically 15–20 pages, single spaced, but may be longer depending on student and advisor preferences. Students should discuss formatting and other expectations for the written portion with their Faculty Advisor in the early stages of preparation for the Comprehensive Exam.

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.
- Demonstrated the ability to conduct significant and original research.
- 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.

3.5.5 Oral Examination Format

The oral exam includes a prepared presentation by the student, followed by a discussion and Q&A session where the student answers questions from the committee. The oral presentation and committee discussion will take approximately 2 hours. The student should prepare a presentation of about 45 minutes that highlights their research topic and the proposed research plan, and addresses the following questions:

- Why is the proposed research of interest, and how does it compare to prior work?
- Is the proposed research challenging enough, and are the expected results significant 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 are then considered *PhD Candidates*. A successful candidate must receive the affirmative votes of the majority of the members of the examination committee. In case of failure, the examination may be attempted once more after a period of time determined by the committee. The student is automatically dismissed by the Graduate School after a second failure. Further details on the Comprehensive Exam format can be found in the Graduate School Policies and Procedures.

Upon completion of the Comprehensive Exam, in addition to completing the form listed in Section 3.5.3 above, students should be sure to inform their research center administrator of their post-Comps status. Graduate Research Assistants (GRAs) are paid a higher stipend post-Comps, but the student must inform their administrator for the change to be made in their GRA appointment. Students receive the post-Comprehensive exam raise starting in the contract pay period that immediately follows the successful completion of the comprehensive exam. See Section 6.3 for a list of appointment contract pay periods.

3.6 Dissertation Defense & Graduation Requirements

After the Comprehensive Exam, the PhD candidate will work with their faculty advisor, and sometimes other faculty, to conduct their funded research and their dissertation research. The research work may include writing and presenting technical papers at conferences and in journals, reviewing technical papers, writing or contributing to research proposals, and mentoring undergraduate, MS, or new doctoral students. Students will also take advanced coursework and complete their Doctoral Practicum (Section 3.3). Both the faculty advisor and the student are responsible for ensuring that the work is adequately progressing. The student should meet with each of the members of their committee at least once per year, or as recommended by the committee at the Comprehensive Exam, to assess progress and to collect feedback.

3.6.1 PhD Dissertation

The dissertation document is based on an original research investigation, showing mature scholarship and critical judgment, and demonstrating expertise in the research field and the tools and methods of the research. The dissertation document must be written on a subject approved by the student's committee chair (i.e. faculty advisor). Each dissertation presented in partial fulfillment of the doctoral degree must:

- Comply with the Graduate School's format requirements and specifications.
- Meet all of the Graduate School's deadlines for defense and dissertation submission in the semester the student will graduate.

The completed dissertation should be submitted to the defense committee at least two weeks (preferably three weeks) before the scheduled defense date. The dissertation submitted at this time should be considered as complete as possible, including feedback and revisions from the student's faculty advisor. However, it is expected that revisions will be required after the defense, based on feedback from the other members of the committee and discussions that take place during the defense.

3.6.2 Doctoral Final Examination (Defense)

After the dissertation has been accepted by the student's committee, a doctoral final examination (i.e. defense) of the dissertation and related topics will be conducted. Similar to the Comprehensive Exam, the defense consists of an oral presentation of the research by the student, followed by a closed discussion and Q&A session with the defense committee. The student's presentation focuses on the research completed over the duration of their PhD career, emphasizing the work conducted, new results, and significant contributions to their research field.

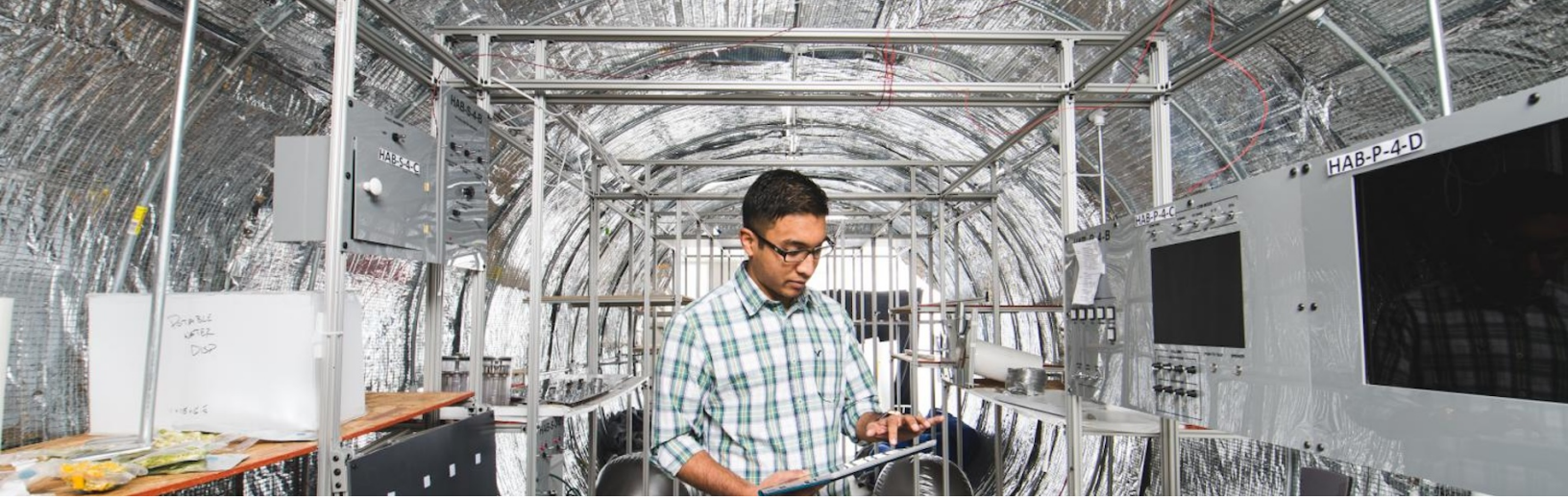
The following requirements must be satisfied:

- Students must have completed at least 30 dissertation credit hours (ASEN 8990) by the end of the semester in which the defense takes place.
- A student must be registered as a regular degree-seeking student at CU Boulder for a minimum of five, and no more than ten, dissertation hours the semester in which the defense takes place.
- **Two weeks prior to the exam**, students submit a copy of the Doctoral Final Examination Form listing their committee members.
- The examination will usually be conducted by the same committee in place for the comprehensive exam. Changes to the committee require faculty advisor approval.
- 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.
- The Doctoral Final Examination Form will be approved by the Graduate School and returned to the department. Following the Doctoral Final Examination, **students must notify the PhD Program Advisor of completion of the exam, and the PhD Program Advisor will initiate routing of the form for signatures from committee members.** When the form is complete, the student will receive a copy for their records.

3.6.3 Final Graduation Requirements

To complete graduation requirements, PhD students must also complete the Thesis Approval Form to ensure that the final copy has been accepted by the thesis committee. The Thesis Approval Form must be uploaded as part of the electronic thesis submission process through UMI/Proquest as a supplementary file. The Thesis Approval Form but be signed by two committee members: the committee chair and any other committee member, and must be signed in advance of the deadline for thesis submission. Students should budget time before the deadline for routing and collecting signatures on the Thesis Approval Form.

For additional graduation tasks, please visit the PhD Advising Page.



4. Focus Area Curricula

Each Focus Area in AES has its own set of curricular requirements for both MS and PhD degrees. These requirements are in addition to the department-wide requirements outlined in Sections 2 and 3 for the MS and PhD degrees, respectively. In most cases, Focus Areas require students to complete a number of **core courses**, and/or to choose from a list of elective courses within the Focus Area. These requirements ensure that students graduate with a depth of specialization in the topics covered by the Focus Area.

4.1 Astrodynamics and Satellite Navigation Systems (ASN)

ASN Specific MS Requirements:

- Three ASN Core Classes from the table below
- One ASEN graduate course from a different Focus Area. The outside course is any ASEN course not listed under the ASN curriculum (in this section).

ASN Specific PhD Requirements:

- There are no specific course requirements for the PhD in ASN beyond the overall departmental requirements.

Core (Required) MS Courses in the ASN Focus Area:

Course Number	Course Title	Offerings
ASEN 5010	Spacecraft Attitude Dynamics and Control	Spring, Annually
ASEN 5050	Space Flight Dynamics	Varies
ASEN 5090	Introduction to GNSS	Fall, Annually
ASEN 5044	Statistical Estimation for Dynamical Systems	Fall, Annually

Elective Courses offered by the ASN Focus Area:

Course Number	Course Title	Offerings
ASEN 6008	Interplanetary Mission Design	Spring, Annually
ASEN 6010	Advanced Spacecraft Dynamics and Control	Fall, Biennially
ASEN 6014	Spacecraft Formation Flying	Fall, Biennially
ASEN 6015	Space Vehicle Guidance and Control	Fall, Biennially
ASEN 6020	Optimal Trajectories	Fall, Triennially
ASEN 6060	Advanced Astrodynamics	Fall, Triennially
ASEN 6070	Satellite Geodesy	Fall, Biennially
ASEN 6080	Statistical Orbit Determination	Spring, Annually
ASEN 6084	Optical Multi-Target Tracking	Fall, Triennially
ASEN 6090	Advanced GNSS Software	Spring, Biennially
ASEN 6091	Global Satellite Navigation System (GNSS) Receiver Architecture	Spring, Biennially
ASEN 6092	GNSS for Remote Sensing of the Atmosphere, Ionosphere, and Earth Surface	Spring, Biennially
ASEN 6519	Celestial Mechanics & Advanced Astrodynamics	Fall, Triennially

4.2 Autonomous Systems (AUT)

AUT Specific MS Requirements:

Students are required to take one course from three of the five topics below:

1. **Control Theory:**
   - ASEN 5014 / ECEN 5448 / MCEN 5448: Linear Control Systems
     Note: These courses are equivalent and only one can be used to satisfy this requirement.
   - ASEN 6024 / ECEN 5738: Nonlinear Control Systems
     Note: These courses are equivalent and only one can be used to satisfy this requirement.
2. **Estimation and Sensor Fusion:**
   - ASEN 5044 Statistical Estimation for Dynamical Systems
3. **Dynamics and Modeling of Vehicles:**
   - ASEN 6114 System Identification for Control
   - ASEN 5128 Small UAS Guidance, Navigation, and Control
4. **Autonomous Decision-Making:**
   - ASEN 5254 Algorithmic Motion Planning
   - ASEN 5264 Decision-Making Under Uncertainty
5. **Programming for Embedded Systems:**
   - ASEN 5067 Microavionics
   - MCEN 5115 Mechatronics and Robotics
   - ECEN 5613 Embedded System Design
   - ECEN 5813 Principles of Embedded Software
   - CSCI/ROBO 5302 Advanced Robotics
     Note: AUT students who have taken ASEN 5254 AND one of the following courses may use these in place of the CSCI 5202/ROBO 5000: Introduction to Robotics prerequisite for this course: ASEN 5044, ASEN 5014 (or equivalent), or ASEN 5114 (or equivalent). Contact the AES or ROBO graduate program advisor for more information.

AUT Course-only MS Requirements:

AUT offers a coursework-only option for the Traditional MS degree. Under this option, the student does not need to complete Graduate Projects, a Certificate, or an MS thesis. The basic requirement for the coursework-only MS degree is:

- Satisfaction of AUT Specific MS Requirements above, plus two additional courses, each from a different topic area in the list above. Topic areas used to satisfy the AUT Specific MS Requirements can be repeated.

AUT Specific PhD Requirements:

- Satisfaction of the AUT Specific MS Requirements.

Elective Courses offered by the AUT Focus Area:

Course Number	Course Title	Offerings
ASEN 5114	Automatic Control Systems	Varies, alternate years
ASEN 5519	Autonomous Bayesian Reasoning	Spring, alternate years
ASEN 5519	UAS in the National Airspace	Varies, alternate years
ASEN 6044	Advanced State Estimation	Spring, alternate years
ASEN 6519	Cooperative Control	Varies, alternate years
ASEN 6519	Cooperative Information Gathering	Varies, alternate years
ASEN 6519	Verification and Synthesis of Stochastic Systems	Spring, alternate years
ASEN 6519	Hybrid Control Systems	Spring, alternate years
ASEN 6519	Optimization: Applications and Algorithms	Fall, alternate years
ASEN 6519	Advanced Survey of Sequential Decision Making	Fall, alternate years

Example Elective Courses offered outside the AUT Focus Area:

See CU Robotics Program courses for full listing.

Course Number	Course Title	Offerings
MCEN 6228	Robust Multivariable Control	Check with ME
ECEN 5138/5638	Control System Analysis/Laboratory	Check with ECEE
ECEN 5458	Sampled Data and Digital Control Systems	Check with ECEE
ECEN 5678	Coordinated Control of Multi-Agent Systems	Check with ECEE
CSCI 5254	Convex Optimzation and Its Applications	Check with CS
CSCI 5322	Algorithmic Human-Robot Interaction	Check with CS
CSCI 5622	Machine Learning	Check with CS
CSCI 5722	Computer Vision	Check with CS
CSCI 5922	Neural Networks and Deep Learning	Check with CS

4.3 Bioastronautics (BIA)

BIA-Specific MS Requirements:

- Students must complete two required core courses:
  - ASEN 5016 Space Life Sciences
  - ASEN 5158 Space Habitat Design
- Students must complete at least one of the following five BIA elective courses:
  - ASEN 5137 Experimental Design and Statistical Methods
  - ASEN 5226 Medicine in Space and Surface Environments
  - ASEN 6116 Spacecraft Life Support Systems
  - ASEN 6216 Human Operation of Aerospace Vehicles
  - ASEN 6316 Extravehicular Activity
- Students much complete at least one of the following non-BIA courses:
  - ASEN 5010 Spacecraft Attitude Dynamics and Control (ASN)
  - ASEN 5012 Mechanics of Aerospace Structures (FSM)
  - ASEN 5014 Linear Control Systems (AUT)
  - ASEN 5044 Statistical Estimation for Dynamical Systems (ASN)
  - ASEN 5050 Space Flight Dynamics (ASN)
  - ASEN 5053 Space Propulsion
  - ASEN 5090 Introduction to Global Navigation Satellite Systems (RSESS)
  - ASEN 5335 Aerospace Environment (RSESS)
  - ASEN 5245 Radar and Remote Sensing (RSESS)
- Students must complete one math course from the approved list below.
  - *Note: If you elect to take ASEN 5044 or ASEN 5137 as an approved math course, it may also count towards the BIA and non-BIA elective requirements listed above.*

BIA-Specific PhD Requirements:

- This specialized field of study addressing human spaceflight is typically augmented with course-work 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.
- Students must complete the two require core courses:
  - ASEN 5016 Space Life Sciences
  - ASEN 5158 Space Habitat Design
- Students must also complete one math course from the approved list below.

Elective Courses offered by the BIA Focus Area:

Course Number	Course Title	Offerings
ASEN 5137	Experimental Design and Statistical Methods	Varies
ASEN 5226	Medicine in Space and Surface Environments	Spring, Annually
ASEN 5849/6849	Independent Study	on request
ASEN 6116	Spacecraft Life Support Systems	Varies
ASEN 6216	Human Operation of Aerospace Vehicles	Varies
ASEN 6316	Extravehicular Activity	Varies

Approved Math Courses:

Course Number	Course Title
ASEN 5044	Statistical Estimation for Dynamical Systems
ASEN 5137	Experimental Design and Statistical Methods
ASEN 5307	Engineering Data Analysis Methods
ASEN 5519	Multi-Object Filtering Theory
ASEN 6412	Uncertainty Quantification
EMEN 5005	Intro to Applied Statistical Methods
ECEN 5612	Random Processes for Engineers
ECEN 5632	Theory and Application of Digital Filtering
CSCI 5636	Numerical Solution of Partial Differential Equations
APPM	Any 4000*, 5000, 6000, 7000 level courses
MATH	Any 4000*, 5000, 6000, 7000 level courses
STAT	Any 4000*, 5000, 6000, 7000 level courses

Note: Up to 6 credit hours at the 4000-level from approved departments may be counted towards the MS degree. 4000-level courses cannot be counted towards the PhD Degree.

4.4 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 courses 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

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 courses in your chosen FSM track

Core Courses Offered by the FSM Focus Area:

Note: Students can elect to take an additional core course in either track to count as an elective.

Fluids:

Course Number	Course Title	Offerings
ASEN 5051	Fundamentals of Fluid Dynamics	Fall
ASEN 5251	Molecular Thermo & Kinetics	Fall
ASEN 5151	Fundamentals of Gas Dynamics	Spring

Structures and Materials:

Course Number	Course Title	Offerings
ASEN 5007	Introduction into Finite Elements	Fall
ASEN 5012	Mechanics of Aerospace Structures	Fall
ASEN 5022	Introduction into Dynamics of Aerospace Structures	Spring

Elective Courses approved by the FSM Focus Area:

Fluids:

Course Number	Course Title	Offerings
ASEN 5053	Space Propulsion	Spring, even years
ASEN 5121	Boundary Layers and Convection	Varies
ASEN 5131	Introduction to Hypersonics	Fall, annually
ASEN 6011	Experimental Fluid Mechanics	Fall, odd years
ASEN 6037 or MCEN 7221	Turbulent Flows or Turbulence	Varies
ASEN 6061	Molecular Gas Dynamics and DSMC	Varies
ASEN 6331	Computational Fluid Dynamics Unstructured Grid	Fall, even years
MCEN 5022	Classical Thermodynamics	Spring, annually
MCEN 5042	Heat Transfer	Spring, annually
MCEN 5151	Flow Visualization	Fall, annually
MCEN 5152	Introduction to Combustion	Fall, annually
MCEN 5231	Computational Fluid Dynamics	Varies
MCEN 6001	Reacting Flows	Spring, even years

Structures & Materials:

Course Number	Course Title	Offerings
ASEN 5111	Aeroelasticity	Varies
ASEN 5148	Spacecraft Design	Spring, annually
ASEN 5218	Large Space Structures Design	Spring, even years
ASEN 5212	Composite Structures and Materials	Spring, odd years
ASEN 5519	Nonlinear Mechanical Vibration	Biennially
ASEN 5519	Design Optimization in Aerospace Systems	Varies
ASEN 5519	Introduction to Phononics	Biennially
ASEN 6107	Nonlinear Finite Elements	Varies
ASEN 6412	Uncertainty Quantification	Spring, even years
ASEN 6519	Molecular Modeling of Material	Varies
CVEN 5161	Advanced Mechanics of Materials I	Check with CVEN
CVEN 6161	Advanced Mechanics of Materials II	Check with CVEN
CVEN 7141	Plates and Shells	Check with CVEN
CVEN 7511	Computational Finite Inelasticity & Multiphase Mechanics	Check with CVEN
EMEN 5405	Fundamentals of Systems Engineering	Check with EMEN
MCEN 5044	Mechanical Behavior of Materials	Check with MCEN
MCEN 5228	Mechanics of Composite Materials	Check with MCEN
MCEN 5228	Mechanics of Soft Materials	Check with MCEN

4.5 Remote Sensing, Earth and Space Science (RSESS)

The expected competency at the MS level in the RSESS Focus Area is to have completed coursework in four primary topics of study. The expected competency at the PhD level is to further advance the four primary topics within RSESS by taking additional advanced graduate courses and through research activities that lead to the PhD dissertation.

MS and PhD students are required to take one course from each of the following topic areas (listed in the tables below):

1. Data or Numerical Analysis Methods
2. Instrumentation Fundamentals
3. Physical Sciences of Earth and Space
4. Astrodynamics and Satellite Navigation Systems (ASN)

Note: 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.

(1) RSESS Data or Numerical Analysis Methods Primary Courses:

Course Number	Course Title	Offerings
ASEN 5307	Engineering Data Analysis	Fall, annually
ASEN 6337	Remote Sensing Data Analysis	Fall, biennially
ASEN 6055	Data Assimilation & Inverse Methods for Earth and Geospace Observations	Fall, biennially
APPM 5350	Methods in Applied Mathematics: Fourier Series and Boundary Value Problems	Fall, annually
ECEN 5612	Random Processes for Engineers	Fall, annually
ECEN 5632	Theory and Application of Digital Filtering	Fall, annually
STAT 5000	Statistical Methods and Applications I	Fall & Spring, annually
STAT 5010	Statistical Methods and Applications II	Fall & Spring, annually
STAT/MATH 5520	Introduction to Mathematical Statistics	Fall & Spring, annually
STAT/MATH 5540	Introduction to Time Series	Spring, biennially

(2) RSESS Instrumentation Fundamentals Primary Courses:

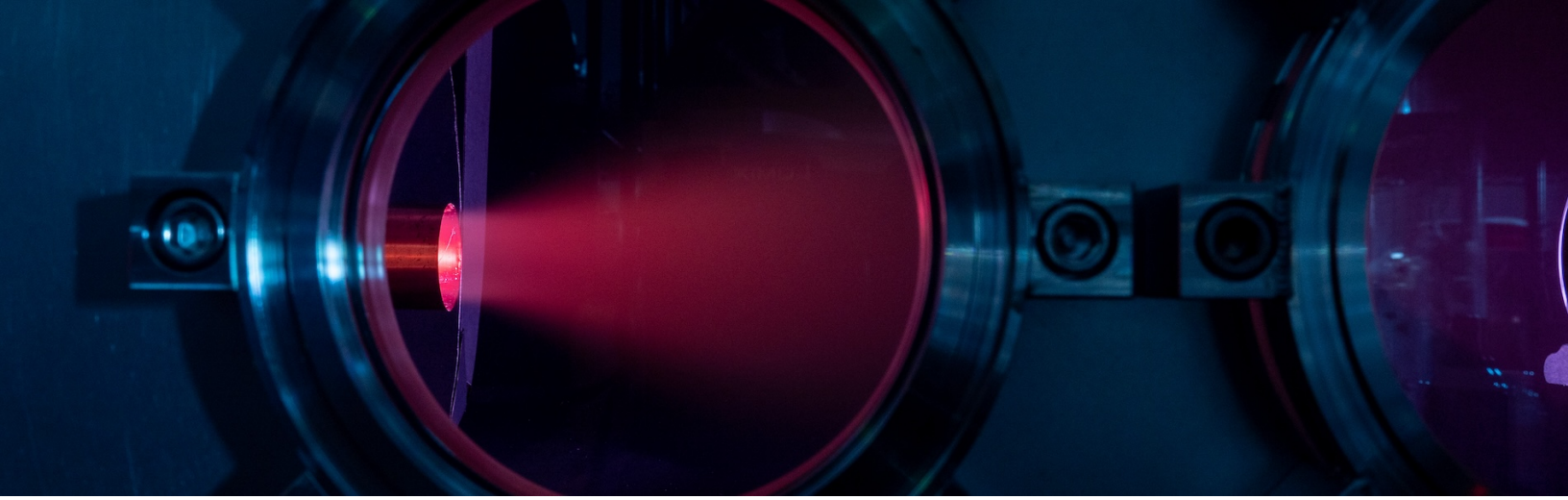
Course Number	Course Title	Offerings
ASEN 5067	Microavionics	Varies
ASEN 5090	Introduction to Global Navigation Satellite Systems	Fall, annually
ASEN 5245	Radar and Remote Sensing	Spring, annually
ASEN 5440	Space Mission Development	Fall, biennially
ASEN 6050	Space Instrumentation	Fall, biennially
ASEN 6265	Fundamentals of Spectroscopy for Optical Remote Sensing	Varies
ASEN 6365	Lidar Remote Sensing	Varies

(3) RSESS Physical Sciences Primary Courses:

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

(4) RSESS ASN Primary Courses:

Course Number	Course Title	Offerings
ASEN 5014	Linear Control Systems	Fall, annually
ASEN 5044	Statistical Estimation for Dynamical Systems	Fall, annually
ASEN 5050	Space Flight Dynamics	Fall, annually
ASEN 5051	Fundamentals of Fluid Dynamics	Fall, annually
ASEN 5148	Spacecraft Design	Spring, annually
ASEN 6070	Satellite Geodesy	Fall, biennially



5. AES Department Certificates

Graduate certificates provide a credential in specific functional areas, demonstrating expertise separate from a graduate degree. Graduate certificate programs deliver knowledge and expertise in demand across many technological fields.

Certificates are designed for master's students and non-degree-seeking students through CU Boulder's Continuing Education program.

General Requirements for Certificates:

- Grades of B or higher are required for fulfillment of requirements and certificate awards.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.
- For degree-seeking students, request certificate enrollment and awarding on our Certificates page. Certificates are awarded at the time of graduation. Review the Academic Calendar for posting and mailing dates.
- Continuing Education / Non-degree students: Please visit our Certificates & Continuing Education page for admissions, enrollment, and other information.

This chapter outlines the certificates administered by the AES department. Section 5.7 provides the complete list of certificates that are approved to satisfy the Traditional MS degree requirements.

5.1 Certificate in Astrodynamics and Satellite Navigation Systems (ASN)

(Open to continuing education students)

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 (18 credit hours).
- Grades of B or higher are required for fulfillment of requirements and certificate award.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

Course Requirements (12 credit hours):

- ASEN 5010: Spacecraft Attitude Dynamics and Control
- ASEN 5044: Statistical Estimation for Dynamical Systems
- ASEN 5050: Space Flight Dynamics
- ASEN 5090: Introduction to Global Navigation Satellite Systems

Notes:

- 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.

Advanced Requirements (6 credit hours):

- Select ANY two 6000 level courses in ASN including, but not limited to, the ASN Electives listed in Section 4.1 and any ASEN 6519 special topics courses offered by faculty in the ASN Focus Area.

5.2 Certificate in Hypersonics

(Open to continuing education students)

This certificate recognizes student accomplishments at the graduate level in successfully completing a specialized program of study in the cross-disciplinary field of hypersonics. It is sponsored by the Ann and H. J. Smead Department of Aerospace Engineering Sciences (AES) and the Paul M. Rady Department of Mechanical Engineering (ME) and involves courses from AES and ME.

The purpose of the certificate is to develop interdisciplinary skills in the field of hypersonics, which requires knowledge about fundamental areas such as gas dynamics, materials, controls, and how their inter-relationships determine hypersonic vehicle performance.

Certificate Requirements:

- The standard requirements of this certificate program are the completion of twelve (12) credit hours of graduate-level coursework (typically four 3-credit courses).
- Grades of B or higher are required for fulfillment of requirements and certificate award.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

Course Requirements:

- ASEN 5131: Introduction to Hypersonics
- Three additional 3-credit courses from the list of Electives

Electives:

- ASEN 5018: Graduate Projects I or ASEN 6028: Graduate Projects II (Specifically focused on hypersonics, approved by certificate coordinator)
- ASEN 5053: Space Propulsion
- ASEN 5121: Boundary Layers and Convection
- ASEN 5151: Fundamentals of Gas Dynamics
- ASEN 5212: Composite Structures and Materials
- ASEN 5519: Hypersonic Vehicle Design Project
- ASEN 5251: Molecular Thermodynamics and Kinetics
- ASEN 5849: Independent Study (Specifically focused on hypersonics, approved by certificate coordinator)
- ASEN 6015: Space Vehicle Guidance and Control
- ASEN 6037 Turbulent Flows or MCEN 7221 Turbulence
- ASEN 6061: Molecular Gas Dynamics and DSMC
- ASEN 6331: Computational Fluid Dynamics or MCEN 5231 Computational Fluid Dynamics
- MCEN 5022: Classical Thermodynamics
- MCEN 5024: Materials Chemistry and Structure
- MCEN 5042: Heat Transfer
- MCEN 5152: Introduction to Combustion
- MCEN 5228: Special Topics in Mechanical Engineering (High Temperature Materials)
- MCEN 6001: Reacting Flows

5.3 Certificate in Radio Frequency Engineering for Aerospace

(For degree–seeking students only)

A joint certificate program between Smead Aerospace and the Department of Electrical, Computer & Energy Engineering. This certificate fills an industry need in Colorado and beyond for cross disciplinary graduate level education in aerospace and electrical engineering. This certificate is open to new and current degree-seeking AES and ECEE students. Non-degree students cannot enroll in this certificate.

Candidates for this certificate must be matriculated graduate students in the AES or ECEE departments. For certificate application and more details, visit the AES Certificates webpage.

This certificate is co-managed by AES and ECEE. Students must follow the rules and policies of each department. Courses from already awarded degrees cannot be used to fulfill certificate requirements.

Certificate Requirements:

- Six courses total (18 credit hours): four required courses (12 credit hours) and two elective courses (6 credit hours).
- Grades of B or higher are required for fulfillment of requirements and certificate award.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

Required Courses (12 credit hours):

- ECEN 5134: Electromagnetic Radiation and Antennas, *or* ECEN 5104: Passive Microwave Circuits
  - If you are interested in taking both courses, one course can count as a requirement and one course can count as an elective. A single course cannot count as both a required course and an elective course, simultaneously.
- ECEN 5634: Microwave and RF Laboratory
- ASEN 5090: Introduction to Global Navigation Satellite Systems
- One of the two courses below, depending on major:
  - ASEN 5148 Spacecraft Design (required for ECEE majors)
  - ECEN 3410 Electromagnetic Waves and Transmission (required for AES majors).
    NOTE: ECEN 3410 will only meet graduate degree/MS requirements for AES students enrolled in the RF certificate.

Elective Courses:

- Students choose 2 out of the following 5 courses:
  - ECEN 5134: Electromagnetic Radiation and Antennas *or* ECEN 5104 Passive Microwave Circuits (whichever is not taken as a requirement)
  - ECEN 5114: Electromagnetic Theory
  - ECEN 5154: Computational Electromagnetics
  - ASEN 5245: Radar and Remote Sensing
  - ASEN 5018 or ASEN 6028: Graduate Projects (Approved RF related project can only count for 1 elective)

5.4 Certificate in Remote Sensing

(Open to continuing education students)

Remote sensing (satellite and ground-based) is increasingly being used as a technique to probe the Earth's geospace, 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:

- 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.
- Grades of B or higher are required for fulfillment of requirements and certificate awards.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

Course Requirements

- Four courses are required, totaling at least 12 credit hours
  - Two courses must be taken from one of the following topical areas:
    - Data Analysis
    - Instrumentation and Measurement Techniques
    - Remote Sensing Theory
  - One course must be taken from each of the remaining topical areas.

Data Analysis Courses:

- ASEN 5307: Engineering Data Analysis Methods
- ASEN 6337: Remote Sensing Data Analysis
- ASTR 5550: Observations, Data Analysis, and Statistics
- ECEN 5244: Stochastic / Environmental Signal Processing
- ECEN 5254: Remote Sensing Signals and Systems

- ECEN 5612: Random Processes for Engineers
- GEOG 5103: Geographic Information Science: Spatial Analytics
- GEOG 5203: Geographic Information Science: Spatial Modeling
- GEOG 5303: Geographic Information Science: Spatial Programming

Instrumentation & Measurement Techniques Courses:

- ASEN 5245: Radar and Remote Sensing
- ASEN 6050: Space Instrumentation (equivalent to ASTR/GEOL 6050)
- ASEN 6091: Global Navigation Satellite System (GNSS) Receiver Architecture
- ASEN 6365: Lidar Remote Sensing
- ASTR 5760: Astrophysical Instrumentation
- ECEN 5134: Electromagnetic Radiation and Antennas
- GEOG 5100: Special Topics: Geography (topic needs to be relevant to instrumentation/measurement)
- PHYS 5160: Fundamentals of Optics and Lasers

Remote Sensing Theory Courses:

- ATOC 5235: Intro to Atmospheric Radiative Transfer and Remote Sensing
- ASEN 6265: Fundamentals of Spectroscopy for Optical Remote Sensing
- ATOC/ASTR 5560: Radiative Processes in Planetary Atmospheres
- ECEN 5264: Electromagnetic Absorption, Scattering, and Propagation
- GEOL/GEOG 5093: Remote Sensing of the Environment
- GEOG 5100: Special Topics: Geography (Advanced Remote Sensing)
- PHYS/ASTR: 5150 Introductory Plasma Physics

5.5 Certificate in Satellite System Design (SSD)

(Open to continuing education students)

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 allows students to develop interdisciplinary skills in the area of satellite design and be more desirable to potential employers.

Certificate Requirements:

- Four courses are required totaling at least 12 credit hours.
- Grades of B or higher are required for fulfillment of requirements and certificate awards.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

The certificate in satellite system design (SSD) offers two track options, both 12 credit hours total:

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

- ASEN 5148: Spacecraft Design
- ASEN 5018 and 6028: Graduate Projects I & II – Projects must have a satellite or rocket focus.
- One course from elective list below

Track 2: Distance Student-Compatible Track

- ASEN 5148: Spacecraft Design
- EMEN 5405: Fundamentals of System Engineering
- Two courses from elective list (Note: no more than one elective can be an EMEN course)

Elective List:

Students are required to meet course prerequisites. Questions should be directed to the course instructor. To develop cross-disciplinary breadth, students are strongly encouraged, but not required, to choose elective courses outside of their major.

- ASEN 5010: Spacecraft Attitude Dynamics and Control
- ASEN 5050: Space Flight Dynamics
- ASEN 5053: Space Propulsion
- ASEN 5067: Microavionics: Introduction to PIC Microcontrollers for Aerospace Systems[1]
- ASEN 5090: Introduction to Global Navigation Satellite Systems
- ASEN 5335: Aerospace Environment
- ECEN 5134: Electromagnetic Radiation and Antennas
- ECEN 5264: Electromagnetic Absorption, Scattering and Propagation
- ECEN 5517: Power Electronics and Photovoltaic Power Systems Laboratory
- ECEN 5613: Embedded System Design
- ECEN 5623: Real-Time Embedded Systems
- ECEN 5634: Microwave and RF Laboratory
- ECEN 5692: Principles of Digital Communication
- ECEN 5797: Introduction to Power Electronics

- ECEN 5813: Principles of Embedded Software
- EMEN 5030: Fundamentals of Project Management
- EMEN 5033: Aerospace Program Management
- EMEN 5405: Fundamentals of Systems Engineering
- EMEN 5415: Introduction to Requirements, Verification and Validation

Notes:

[1] Course Enrollment is limited to non-Electrical Engineering students.

5.6 Certificate in Space Weather and Applications

(Open to continuing educations students)

This certificate provides students with interdisciplinary skills in the field of space weather. The requirements enapsulate fundamental processes in science and practical applications to space-based and ground-based technology.

Certificate Requirements:

- Four courses are required totaling at least 12 credit hours.
- Grades of B or higher are required for fulfillment of requirements and certificate awards.
- Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

Course Requirements:

- ASEN 5335: Aerospace Environment
- Two courses from the Tier 1 Electives List
- One additional course from the Tier 2 Electives list
- At least one course must be outside the student's home department if pursuing a graduate degree

Tier 1 Foundational Elective list[1,2]

- ASEN 6050: Space Instrumentation (equivalent to ASTR/GEOL 6050)
- ASEN 6365: Lidar Remote Sensing
- ASTR 5140: Astrophysical and Space Plasmas (equivalent to PHYS 5141)
- ASTR 5150: Introductory Plasma Physics (equivalent to PHYS 5150)
- ASTR 5300: Introduction to Magnetospheres
- ATOC 5050: Atmospheric Thermodynamics and Dynamics
- ATOC 5235: Intro to Atmospheric Radiative Transfer and Remote Sensing

Tier 2 Concentration/Focus Elective list[2]

- **Applications:**
  - ASEN 5016: Space Life Sciences
  - ASEN 5090: Introduction to Global Navigation Satellite Systems
  - ASEN 6265: Fundamentals of Spectroscopy for Optical Remote Sensing
- **Design & Instrumentation:**
  - ASEN 5158: Space Habitat Design
  - ASEN 5440: Mission Design and Development for Space Sciences (equivalent to ASTR 5780)
- **Radiative Processes & Atmosphere Coupling:**
  - ASTR 5120: Radiative and Dynamical Processes
  - ATOC 5560: Radiative Processes in Planetary Atmospheres (equivalent to ASTR 5560)
- **Electromagnetics & Plasma:**
  - ASTR 7160: Intermediate Plasma Physics (equivalent to PHYS 7160)
- **Data Science:**

  - ASEN 6055: Data Assimilation & Inverse Methods for Earth & Geospace Observations
  - APPM 5510: Data Assimilation in High Dimensional Dynamical Systems (equivalent to STAT 5250)
  - STAT 5000: Statistical Methods and Applications I
  - STAT 5010: Statistical Methods and Applications II

- **Selected Topics[3]:**
  - ASEN 5519/6519: Special Topics
  - ASTR 5830: Topics in Planetary Science (equivalent to ATOC/GEOL 5830)
  - ASTR 7500: Special Topics in Astrophysical and Planetary Sciences[2]
  - ATOC 5500: Special Topics in Atmospheric and Oceanic Sciences[2]

Notes:

[1] Students are required to meet course prerequisites. Questions should be directed to the course instructor.

[2] If cross-listed in the student's home department, a course cannot count as the outside course within the certificate for students pursuing a graduate degree.

[3] For courses with rotating topics, a particular offering must be on a topic relevant to space weather in order to count for this certificate. These courses will need approval from the program director.

5.7 List of Approved Certificates

In addition to the six certificates adminstered by AES and listed above in Sections 5.1 through 5.6, the following certificates are approved to meet the requirements of the Traditional MS degree.

5.7.1 Interdisciplinary Certificates

Interdiscipinary certificates provide expertise in highly interdisciplinary topic areas, often requiring courses from multiple departments. Some of the most popular interdisciplinary certificates include:

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

5.7.2 Allied Field Certificates

A number of certificates offered in other departments may be of interest to many AES students. The lists below provide a few potentially interesting certificates, but are not meant to be comprehensive.

Certificates in Electrical and Computer Engineering (ECEN):

- Embedded Systems Engineering
- Power Electronics
- Photonics
- Electric Drivetrain Technology
- Radio Frequency (RF) Engineering for Aerospace (Joint with ASEN)

Certificates in Engineering Management (EMEN):

- Engineering Management
- Innovation & Entrepreneurship in Engineering
- Leadership & Management
- Project Management

Certificates in Certificates in Mechanical Engineering (MCEN):

- Advanced Mechanics & Failure Analysis
- Biomedical Engineering
- Food Engineering
- Mechanical Design & Product Development

Certificates in Engineering Topical Areas:

- Water Engineering & Management
- Data Science Graduate Certificate (on-campus offering, not Coursera)

5.7.3 Certificates Requiring Pre-Approval

Certificates not listed above require department approval to be counted towards the MS degree requirements. Please complete a Petition for the AES graduate program to review.

Interdisciplinary Certificates:

- Behavioral Genetics (for PhD students only)
- Biotechnology
- Cognitive Science
- Development Studies
- Geophysics
- Hydrologic Sciences
- Astrobiology

6. Appointments

The education and research environment in AES relies on the hard work and contributions of the faculty, staff, and students. PhD students are most commonly funded through Graduate Research Assistantships (GRA), but may also hold Graduate Teaching Assistantships (GTA). Masters students can also become involved with the department through Teaching Facilitator (TF) or GRA appointments. These appointments not only provide the student with valuable experience and compensation, but they critically contribute to the successful operation of the department each semester.

Graduate students can be employed by the AES Department with three different types of positions:

- GRA or GTA: these positions include salary compensation, by semester, with tuition support.
- TF: these positions include salary compensation, by semester.
- Hourly paid positions, for research, grading, or other activities in the department.

Additionally, graduate students can be supported through external fellowships or with personal funds. Note that some fellowships from external sponsors (e.g. NASA FINESST or NSTGRO) are administered through the university, in which case the student may fall under the GRA employment category above.

Please see the Graduate School's Graduate Student Appointment Information page for more details.

6.1 Appointment Percentage

The majority of department GRA and GTA positions have a 50% AY appointment (20 hours per week); the remaining time is dedicated to coursework and/or dissertation research. Some positions may have summer appointments up to 40 hours/week, but this is determined by the supervisor. A GRA/GTA can hold no less than a 15% appointment to receive tuition remission. Any appointment that exceeds 50% during the academic year requires special approval by the Graduate School. The maximum possible appointment is 62.5% during an academic semester, counting all positions and after approval of the 12.5% overage appointment.

6.2 Tuition

GRA and GTA positions are additionally compensated with **tuition remission**. Tuition remission means the department pays the university for the student's tuition; in the case of a GRA, tuition is typically paid from the faculty advisor's research funding. For GTA positions, the department pays the student's tuition remission directly. Tuition remission covers tuition, mandatory fees, and a percentage of the Gold Comprehensive Insurance Plan, provided that the student works at least 12 weeks of the appointment contract period. It is the student's responsibility to pay the remainder of the insurance and any remaining fees.

Note: TF positions and hourly positions do not include tuition remission; students are required to pay the full amount for tuition and fees.

6.3 Appointment Periods (GRA & GTA Only)

Appointments follow the University holiday schedule and not the class schedule. Appointments are by semester, and are valid for the following dates:

- Fall: August 15 through December 31
- Spring: January 1 through May 15
- Summer: May 16 through August 14

Note: GRA and GTA appointments are independent of the class schedule. For example, the University is officially closed only on the Friday of spring break, not for the entire spring break week. Students are therefore expected to work during the week of spring break even though there are no classes that week, unless arrangements have been made with their supervisor.

6.4 Leave

Students should consult their employment offer letter for details on sick leave. Students on a Graduate Appointment (GRA, GTA, or GPTI) are not eligible for paid vacation leave.

Students should discuss personal time off with their supervisor before making travel arrangements or arranging for time off. If a student expects to be away from their position for an extended period of time, their supervisor has the option to put the position on a short work break, without pay, or to reduce their appointment percentage for the semester to account for time off.

7. Other Important Information

7.1 Approved List of Prelim Courses

Students signing up for the preliminary exam choose one in-focus-area course and one out-of-focus area course for their examination. The lists below overlap with the core courses in each focus area; however, students should verify that a course is in the list below before choosing it for their exam.

Astrodynamics and Satellite Navigation Systems (ASN)

- ASEN 5010: Spacecraft Attitude Dynamics and Control
- ASEN 5044: Statistical Estimation for Dynamical Systems*
- ASEN 5050: Space Flight Dynamics
- ASEN 5090: Introduction to Global Navigation Satellite Systems

Note: ASEN 5044 cannot count as an out-of-focus area topic for ASN.

Autonomous Systems (AUT)

- ASEN 5014: Linear Control Systems
- ASEN 5044: Statistical Estimation for Dynamical Systems*
- ASEN 5254: Algorithmic Motion Planning
- ASEN 5264: Decision-Making Under Uncertainty

Note: ASEN 5044 cannot count as an out-of-focus area topic for AUT.

Bioastronautics (BIA)

- ASEN 5016: Space Life Sciences
- ASEN 5158: Space Habitat Design

Fluids, Structures and Materials (FSM)

Fluids:

- ASEN 5051: Fundamentals of Fluid Dynamics
- ASEN 5151: Fundamentals of Gas Dynamics
- ASEN 5251: Molecular Thermodynamics & Kinetics

Structures:

- ASEN 5007: Introduction into Finite Elements
- ASEN 5012: Mechanics of Aerospace Structures
- ASEN 5022: Introduction into Dynamics of Aerospace Structures

Note: FSM students can take their in-focus area core course from one track (i.e. Fluids) and the out-of-focus area course from the other track (i.e. Structures).

Remote Sensing, Earth and Space Science (RSESS)

- ASEN 5245: Radar and Remote Sensing
- ASEN 5307: Engineering Data Analysis
- ASEN 5335: Aerospace Environment

7.2 Independent Study

Independent Study (IS) is self-directed exploration of a topic of mutual interest with a faculty member. It is an opportunity to work with individual direction and guidance from a faculty member on a specialized area of study that you feel is important to research. A student may propose an independent study to any appropriate member of the graduate faculty. Faculty may sign an independent study agreement if they agree with the following:

- The topic is worth investigating
- The student has sufficient background in the topic
- The topic is not covered in sufficient depth in departmental courses
- They share enough interest in the topic to sustain the project

Notes:

- Faculty are under no compulsion to accept independent study students, but do so as their work load permits.
- Independent Study credit may not be given for internship experiences, work for pay within or outside of the program, or volunteer work.
- One credit of Independent Study should equate to about 45 hours of work over the course of the semester.
- The agreement form on the Graduate School website must be submitted to the Graduate Coordinator before or within the first 10 days of the semester.

What constitutes a graduate independent study?

A Graduate Independent Study is intended to advance a graduate student's academic progress. The study should help the student build knowledge and/or develop skills necessary for their degree or their future research. The independent study must not itself constitute the research that leads to the MS or PhD dissertation. The independent study must therefore meet the following requirements:

- Have one or more learning objectives and/or deliverables, appropriate for the graduate level
- Be independent of any funded research
- Be independent of the student's current MS or PhD dissertation research

Advanced Graduate Independent Study: ASEN 6849

6000-level courses in ASEN are considered "Advanced Graduate Courses," and by definition have a graduate-level course (at the 5000 level) as a prerequisite.

If a student wishes to enroll in ASEN 6849, the independent study proposal must show that the topic under study either i) has a graduate-level course as a prerequisite to the study topic, or ii) constitutes the "advanced" second phase of a previous 5000-level independent study.

Expectations for MS vs. PhD students

Dissertation or funded research should not be used for independent study credits. This applies to both Master's thesis and PhD thesis research.

For MS students not pursuing a thesis, the independent study is more flexible: it may provide some research experience in the advisor's lab, but must still have a primarily academic intent, and a clear set of evaluation criteria.

The separation of dissertation or funded research is primarily to protect the student. Students pay tuition

for courses, including independent study; on the other hand, students are typically paid to work on funded research projects. Students should not be paying tuition dollars to contribute to funded research.

Independent Study evaluation

It is the responsibility of the independent study supervisor (faculty member) to create a rubric for evaluation of the IS. The rubric creates an agreement between the student and the advisor for deliverables and grading expectations. Similar to any other course, the student should know ahead of time the work required to complete the IS, how the work will be evaluated, and the criteria for grade determination. At a minimum, the Independent Study proposal should include:

- A list of expected deliverables (reports, hardware, literature reviews, etc.)
- A rubric for each deliverable's contribution to the final grade

What to include in the Graduate Independent Study Proposal Form

To be considered for approval by the Graduate Program, the Graduate Independent Study proposal form should include the following:

- Describe the purpose and academic goals of the proposed Independent Study (IS).
- Describe the method of conducting and evaluating the IS (for example: research and reading, written reports, regular meetings and discussions, final paper or report).
- Describe how the IS will be evaluated. Indicate any specific assignments, dates when they are to be finished, and how they will contribute to the final grade.
- If enrolling in ASEN 6849, provide justification and describe the prerequisite course or previous independent study.
- If necessary, explain how this work differs from your MS/PhD research or any funded projects.

Only use the Smead AES form if you are planning to do an independent study with a faculty member in Smead AES. If you are planning independent study with a faculty member in another department, you will need permission from that department to enroll in their independent study course, so reach out to their graduate coordinator/graduate program advisor for instructions.

The Graduate Independent Study Proposal Form can be found on the department's Forms for Graduate Students page.