Smead Aerospace
UNIVERSITY OF COLORADO **BOULDER**

Graduate Student Handbook

2022 / 2023 Academic Year
Effective August 1, 2022

Ann & H. J. Smead Department of Aerospace Engineering Sciences
University of Colorado Boulder

1 Foreword

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

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

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

This handbook details the opportunities, requirements, and expectations for graduate studies in AES. In addition to the rules set forth in this Graduate Handbook, all students are also subject to the rules and provisions required by CU Boulder's Graduate School. These rules and provisions can be found on the Graduate School website.

COVID-19 statement:

We understand that the COVID-19 pandemic has been disruptive and deeply challenging to students, staff, and faculty. In response to these events, we recognize that our graduate students will have concerns about the impacts these events could have on their academics. We want to be clear that we understand that:

- Students have been facing and will face unprecedented challenges during this time.
- Many students and institutions have chosen to adopt the Pass/Fail (or Credit/No Credit) option due to these events.
- Due to this disruption students may not have performed to their usual abilities during times of remote study or challenging classroom adjustments
- Some research projects will have been interrupted or will be incomplete as a result of university and facility closures.
- Many students will be unable to take on internships and summer research programs or other professional development initiatives.
- There are myriad other challenging circumstances that have arisen in individuals' experiences.

As you progress through your graduate career in our department, we will take into consideration the impact that his pandemic has had for many of us and provide accommodations and flexibility, within reason and when necessary, to assure your success. Please review campus and college-wide communications regarding COVID-19, as well as the departmental newsletter, webpage, and communications from graduate academic advisors and others in the department.

CU Boulder's COVID-19 Resources:

- The Graduate School's COVID-19 FAQs
- CEAS Pass/Fail Grading Policy for Spring 2020
- CU Boulder's COVID-19 Updates
- Counseling and Psychiatric Services (CAPS)
- Office of Diversity, Equity & Community Engagement (ODECE)

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2 Focus Areas

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

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

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

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

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

3 Key Contacts

Graduate Advisors: The graduate advisors (Graduate Program Advisors, 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: The GPM advises all PhD students and supervises the other Graduate Advisors.

Nicole Simmons
Graduate Program Manager
nicole.m.simmons@colorado.edu

Graduate Program Advisors:

Maureen Craig

BAM Program and Certificate Programs Graduate Advisor

Maureen.Craig@colorado.edu

Madeline Job

MS Graduate Advisor

Madeline.Job@colorado.edu

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

Professor Jay McMahon
Associate Chair for Graduate Studies
Ann & H.J. Smead Department of Aerospace Engineering Sciences
Jay.mcmahon@colorado.edu

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

Professor Hanspeter Schaub
Department Chair
Ann & H.J. Smead Department of Aerospace Engineering Sciences
aeschair@colorado.edu

4 Academic Standards

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

Students who wish to drop a course after the drop deadline must show that they were unable to drop the course during the posted deadlines due to documented reasons that were beyond their control. An incomplete (I) grade is given only when students, for documented reasons beyond their control, have been unable to complete course requirements in the semester enrolled. A substantial amount of work must have been satisfactorily completed before approval of such a

grade is given. At the end of one year, a grade of “I” given for a course that is not successfully completed or repeated is regarded as an F and shown as such on the student’s transcript.

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

Students should refer to the version of the Graduate Handbook in effect at the time of their matriculation for degree plan requirements. Students who are readmitted or continue on from the MS to the PhD program are subject to the handbook in effect at the time of their continuation start date. Please visit CU Boulder’s Graduate School website and review their Policies and Procedures.

In addition to rules contained within the 2022-2023 version of the Grad School handbook, the following two department-specific rules apply:

- PhD students are required to have a 3.25 GPA or above to be admitted to candidacy.
- Grades below a B- will not be counted towards degree requirements for any graduate students (MS or PhD).
- 4000 level courses do not fulfill PhD degree requirements

5 Expectations

5.1 Student Expectations

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

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

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

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

research interest. You are also encouraged to present your research at seminars as opportunities arise.

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

*Note: **Five credit hours is a full-time load for most graduate students**. Under special circumstances, doctoral students and masters students completing a thesis are considered to be at full-time status with less credits. Please consult the Graduate School Rules or reach out to your graduate program advisor for details.

5.2 Faculty Expectations

Similarly, you may expect certain standards from your professors. It is the professor's responsibility to clarify their policies regarding time off, work hours, publication authorship, funding, etc. early on; it is your responsibility to make sure she/he does so. Your professors will guide you in your research, teaching, and professional development, and assist you with post-graduation job placement. They will provide you with opportunities for industry or laboratory internships and encourage your attendance at professional conferences. Your professor will provide you with an annual evaluation of your progress in meeting your degree requirements and in your research, and if you have a Research Assistant appointment, financial support is guaranteed so long as you make acceptable progress (as determined by your advisor) and there are available funds.

5.3 Disagreements (non-grade-related)

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

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

6 Master of Science Degree

The Master of Science (MS) in Aerospace Engineering (ASEN) 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:

Traditional MS –Study is aligned with one of the focus areas. This choice requires completion of focus area-specific curricular requirements and one of the four options below:

- MS thesis – engage in meaningful research resulting in a thesis document and successful thesis defense. Students are required to complete 6 credit hours of ASEN 6950 (Master's Thesis).
- Complete Graduate Projects I and II (ASEN 5018 and 6028) (see section 6.4.2 and our Graduate Projects page).
- Complete an approved certificate (See Appendix C and our Certificates Page).
- Fulfill requirements for focus area-specific course-based MS curriculum.

Focus Area	Focus Area-specific course-based MS	Certificate(s) available
ASN		x
AUT	X	
BIO		
FSM	X	
RSESS		X

Professional MS (ProMS) - Offers a more flexible, course-based curriculum, not aligned with a specific Focus Area curriculum.

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

6.1 Common Requirements for all MS options

- 30 credit hours total (equivalent to 10 classes for most focus areas):
  Note: Most of our graduate courses are 3 credit hours.
  - 24 credit hours or more must be completed at the 5000 level or above.
  - 18 credit hours or more in ASEN courses. (Note: EMEN 5405 *Fundamentals of Systems Engineering,* counts as an ASEN class).
  - 3 credit hours, equivalent to one class, of an approved mathematics course. See Appendix B.
- Up to 6 credit hours can be taken at the 4000 level in related engineering, math and science departments (ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDB, APPM, MATH, CHEM, IPHY, GEOL, ENVD, STAT).
  *Note: ASEN courses 4000 and below do NOT fulfill degree requirements.
- Courses taken in non-related departments do not fulfill degree requirements.
- With the exception of the Remote Sensing Certificate, seminar credit hours (even those earned in other disciplines) do not count toward the MS degree.
- Completion of all degree requirements within four years. Two years is the average time of completion in our department.
- If a student is admitted on a provisional basis, a GPA of 3.25 must be maintained for each semester until 12 credit hours are completed, or the student will be suspended.

- Provisional students are required to take a minimum of 12 hours of graduate coursework over a period of 4 semesters.
- Additional conditions may be placed on a provisional student at the discretion of the department, to account for individual circumstances.

6.2 Professional Master of Science Degree

The Professional Master 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 to follow Focus Area-specific curricular requirements. International and non-resident students seeking a more affordable degree option and students who desire a more flexible and customized degree program that does not require fulfillment of focus area-specific requirements and curricula will benefit from this flexible degree program.

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

6.3 Traditional MS Program Requirements

In the Traditional MS program, students choose one of the Focus Areas for specialization. As a requirement, they must complete a series of courses designed by the Focus Area to provide the fundamentals of the field. This includes two to four required courses (6-12 credit hours) in the student's Focus Area and one required course (3 credit hours) that must be taken in a second Focus Area, *sub-track or **topic (*i.e. FSM, sub-track, **AUT and RSESS, topics). More details for the specific course sequences can be found in Appendix A. Students are also required to complete one of these options:

- MS thesis - completion of 6 thesis credit hours (ASEN 6950).
- Graduate Projects I and II (ASEN 5018 and 6028).
- Required courses leading to an approved certificate, or to completion of the dual Aerospace Engineering and Engineering Management MS degree (ASEN/EMEN). Please visit the previous link for more details or contact Madeline Job (madeline.job@colorado.edu), ASEN Graduate Advisor, or Kendra Thibeault (kendra.thibeault@colorado.edu), EMEN Graduate Coordinator.
- Course-based MS requirements determined by student's Focus Area.

6.3.1 MS Thesis

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

- Completion of six credit hours of ASEN 6950 (MS Thesis).

- Comply with the Graduate School's format requirements and specifications.
- The examination committee for the MS thesis will consist of three regular graduate faculty members, two of which must be in the Aerospace Engineering Sciences department.
- Defend and submit 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

6.3.2 Non-Thesis Course Work: Graduate Projects

*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 with prior approval of the project advisor only.

6.3.3 Non-Thesis Course Work: Certificate

In a MS Certificate option, graduate students explore an interdisciplinary area while pursuing a master's or doctoral degree in a specific department and 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, please see Appendix C.

***Note:** For all AES certificates, **students must obtain grades of B or higher** in all courses towards certificate completion to be awarded the certificate. Double-counting courses to obtain two or more certificates is not allowed. Please see Appendix C for details and AES certificate requirements. For certificates in other departments, including Engineering Management, reach out to their graduate program advisors or coordinators.

6.3.4 Non-Thesis Course Work: Focus Area-Defined Courses

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

6.4 Bachelor's-Accelerated Master's Program (BAM)

The Bachelor's–Accelerated Master's (BAM) degree program options offer currently enrolled CU Boulder's undergraduate students the opportunity to receive a bachelor's and master's degree in a shorter period of time. You will receive the bachelor's degree first, but begin taking graduate coursework as undergraduates (during your senior year). Because some courses are allowed to double count for both the bachelor's and the master's degrees, you will 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 a bachelor's–accelerated master's program will allow you to continue working with your established faculty mentors.

6.4.1 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
  - ASEN coursework is any ASEN 2000-level course and above (excluding ASEN 3036 & ASEN 3046).
  - *Note: If you took your first ASEN 2000-level course in summer 2020 or earlier, the GPA requirements are a 3.25 for both the cumulative GPA and ASEN 2000-level and higher coursework. Please email the BAM Program Advisor if this is your situation prior to submitting your application.*
- Complete MAPS requirements or be enrolled in the courses required to complete these requirements

6.4.2 Program Requirements

You may take up to and including 12 hours while in the undergraduate program which can later be used toward the master's degree. However, only 6 credit hours may be double counted toward the bachelor's degree and the master's degree. You 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.

6.4.3 Applying to the BAM Program

- April 30 - Application Opens
- June 30th - Application Closes
- Students can apply the semester before enrolling in ASEN 4018 - Senior Projects 1: Design Synthesis. For enrollment prerequisites, refer to the catalog pages.

In preparation to apply, please revise these resources:

- The Graduate School's pages contain important information for prospective and current graduate students
- The Graduate School Rules 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.

6.4.4 Resources for students currently admitted to BAM

- It is expected from all BAM and graduate students to be fully familiarized with the content of the handbook and MS degree and Focus Area requirements.
- BAM students can choose from any of the MS degree paths, with the exception of the dual MS in ASEN and EMEN.
- The Graduate School Rules provide detailed information on credit enrollment limits, academic probation, credit transfer rules, and other subjects
- 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.

6.5 Transfer of Credits for all MS students:

- Transfer credit is any credit earned prior to matriculation into the graduate program.
- Students can request a Transfer of Credit upon completing 6 credit hours as a degree-seeking student at CU Boulder.
- Up to 9 credit hours from an incomplete MS program may be accepted for degree requirements; however, work already applied toward a graduate degree received from CU Boulder or another institution cannot be accepted for transfer toward another graduate degree at the same level at CU Boulder.
- *Credit hours used to fulfill undergraduate degree requirements are not transferable.
- Coursework completed for a doctoral degree may not be applied toward a subsequent master's degree.
- Extension work completed at another institution cannot be transferred; and correspondence work, except to make up deficiencies, is not recognized.
- Up to 9 credit hours of CU Boulder coursework taken through Continuing Education can be transferred towards an MS degree.
- Review the Graduate School Rules for additional information
- To request credits transfer, complete the Transfer of Credit Request, fields 1-11 and email your graduate program advisor.

*Note: Students pursuing the ASEN BAM or BS/MS Program are exempt from this rule and shall abide by BAM or BS/MS rules, Section 6.4 of this handbook.

7 Ph.D. Degree

7.1 Faculty Advisor

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

An advisor may choose to no longer serve as a student's faculty advisor by providing written electronic notice to the student and the Associate Chair for Graduate Studies. To continue graduate studies in the PhD program, a student receiving such a notice must find a new AES

graduate faculty advisor within 120 days of notice from the previous advisor. The new faculty advisor must provide written electronic notice indicating their willingness to serve as the student's faculty advisor to both the student and the Associate Chair for Graduate Studies. If the student is unable to find a new faculty advisor within 120 days the student will be removed from the PhD program; If the student does not already possess a M.S. degree, then rather than dismissal from the PhD program their degree program will be changed to the M.S. program.

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

7.2 Program Requirements

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

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

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

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 major advisor and/or appropriate departmental personnel. To continue, 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 major advisor and/or other appropriate departmental personnel and may be granted for up to one year.

7.3 Doctoral Practicum

○ 7.3.1 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 awarding of a doctorate. 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 skill 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/impact to others
2) Provide intrinsic value to the student's professional or personal development
3) Leverage the intellectual rigor consistent with the expectations conferred upon an individual who has earned their PhD

■ 7.3.2 Examples

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

- Participation in the GPTI or iTA program for one semester
- Team teaching a course with AES faculty member

● Significant service activities - outreach, student organization, inclusive excellence committee
● Mentor for undergraduate or MS student research including, but not limited to UROP, Discovery Learning Apprentice, SURE or SMART students or high school students
● 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 need or support underserved populations

■ 7.3.3 Process

It is expected that the DP will be formative and require intellectual effort. Acknowledging that this can occur over varied timescales, the estimated duration should be at a minimum of 1 week of full-time work (40 hours). 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. The DP plan must be approved prior to the student passing the Comprehensive Exam.

- Step 1: It is recommended the student 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: Prior to the Comprehensive Exam, the student submits a **1-page** DP proposal. 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 graduate committee chair. If rejected, the student should revise and resubmit the DP plan for approval based on feedback prior to transitioning to a Doctoral Candidate.

- Step 3: Prior to the Defense, the student shall submit evidence demonstrating completion of the DP using the DP Form. This form includes a **1-page** letter acknowledging the student's DP activities. The letter may not be written by the student or their faculty advisor. The form must be signed by the student, faculty advisor, and PhD GPA.

Examples of acceptable DP acknowledgement letters:
● TA/TF appointment - letter from the instructor of record summarizing the performance of the student, or from a student in the class stating the personal impact of the DP student's work.
● Mentoring - a letter from the student(s) mentored, describing the activities and support provided by the PhD student mentor.
● Outreach activities - letter from outreach advisor or from one from a participant describing the value of the activities and role of the PhD student.

● Internship/entrepreneurship activities - letter from supervisor or client describing the contributions of the PhD student.

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

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

■ 7.4.1 Preliminary Exam

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

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

7.4.2 Format

The Preliminary Exam is composed of an Oral Exam in front of a committee of three graduate teaching faculty members that focuses upon both research preparation and fundamental knowledge in key subject areas.

The Oral Exam will be composed of three components:

1. A Presentation summarizing the literature review conducted by the student followed by an Examination of the presented concepts
2. An In-Focus-Area Fundamental Subject Area Exam
3. An Out-of-Focus-Area Fundamental Subject Area Exam

The research portion of the exam will be composed of both a written literature review not to exceed 2 pages of text with an additional page allotted for references and a brief 5-10 minute oral presentation by the student not to exceed 5 prepared slides summarizing the literature surveyed, and given at the start of the Oral Exam. The topic of the literature review shall be determined by the student and their primary research advisor and will be assigned no later than two weeks prior to the start of the preliminary examination period. It can focus around a detailed review of a single paper or broader review of multiple works relevant to the student's main research focus. As a result, this literature review is intended to prepare the student for their on-going 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 literature review must be emailed to the Oral Exam Committee members, directly by the student, prior to the department-wide due date that will be set each year.

Each of the Oral Exam components is expected to take approximately 30 min. with a total exam duration of up to 2 hours (allowing for an additional 30 min. of deliberation by the committee without the student present). The Oral Exam will be scheduled by the Graduate Advising Staff during a 2 week period based upon the availability of the Preliminary Exam Committee Members. Note, due to the scheduling challenges 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. 8am - 5pm Monday - Friday).

The Oral Examination will begin with a brief 5-10 min. presentation by summarizing the literature they surveyed, highlighting the key conclusions of the work and potential directions for future research. Following this presentation, the Preliminary Exam Committee members will ask questions of the student about their literature review (written & presented). 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 questioning and discussion in the two Fundamental Subject Area 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 Oral 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 out the details on the white board students will provide the Exam Committee a better understanding of their knowledge and problem solving skills.

The two fundamental subject areas will be selected by the student. One subject must be selected from topics within the student's primary Focus Area and the other subject area must be selected from outside of the student's primary Focus Area. Appendix F presents a listing of Prelim Courses that identify the subject areas by 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.

7.4.3 Committee

The Preliminary Exam committee consists of three ASEN graduate teaching faculty members. For courses cross-listed outside of ASEN, graduate faculty from other departments teaching the course are permitted but not required to serve on Preliminary Exam Committees. The student's PhD advisor must be one of the members of the Preliminary exam committee and will serve as the committee chair. If the student is co-advised or has multiple PhD advisors, then only one may serve on the Preliminary Exam committee. The remaining two committee members will be appointed by the Focus Area Leads based upon the selection of fundamental subject areas 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.

7.4.4 Subject Matter

As highlighted above, Appendix F presents a listing of Prelim Courses that identify the fundamental subject areas by Focus Area. While students are not required to take these courses for academic credit, they are strongly encouraged to take these courses 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.

■ 7.4.5 Logistics

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

■ 7.4.6 Grading and Outcomes

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

After the exam is complete, the committee members will confer to determine the exam outcome. For each topic including research, the committee will determine one of three possible outcomes:

1. Pass
2. Delayed Decision
3. Fail

This grading evaluation will represent a combined assessment for both the written and oral components. Each committee member will assess each topic area with one of the following scores: E - Excellent, S - Satisfactory, U - Unsatisfactory. If a topic receives one score of Unsatisfactory the outcome for that topic is a Delayed decision. If a topic receives two scores of Unsatisfactory the outcome is a Fail and the student must retake that area the next fall. The student may switch to a different topic for the next round if the outcome is Fail.

In the case of a Delayed Decision, the student must satisfy the Delayed Decision conditions provided by the examination committee in the examination form 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 Unsatisfactory and a student must either retake the exam in that topic or leave the PhD Program.
The student may switch to a different topic for the next round if the outcome is Fail.

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

In the second and third year of the program, PhD students who have successfully passed the Preliminary Exam work on advancing their specialized technical expertise. In

collaboration with their advisor, students begin the process of defining their specific doctoral research topic.

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

■ 7.5.1 Comprehensive Examination Requirements & Logistics

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

The following are additional requirements for the comprehensive examination:

- Completion of required coursework for the PhD degree with the exception of remaining dissertation credits
- The student must be at full time status the semester taking the comprehensive examination
- A student shall have earned at least four semesters of Residence (see PhD program requirements), have a GPA of 3.25 for all graduate ASEN or CU coursework, and shall have passed the Comprehensive Examination before admission to candidacy is approved by the Graduate School.
- The Comprehensive Examination must be taken at least one semester before the Final Exam.

The Comprehensive Exam is typically administered by the expected Dissertation Committee (see section 7.5.2). This committee will serve as the examining board for both the Comprehensive Examination and Final Defense Examination. Outside committee members require the Graduate School's approval. Students must submit a copy of the outside member's CV to their Graduate Program Advisor four weeks prior to the exam date so that a Graduate Faculty Membership can be requested for that member. Failure to submit these requests in a timely manner may result in a delay in the exam.

Forms and Logistics:

- 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.
- 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.

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

7.5.2 Dissertation Committee Composition

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

Outside committee members must be approved by the Graduate School and receive a special Graduate Faculty Appointment (GFA). 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 outside committee member, when necessary. Additional documents may be necessary to complete the request.

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

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

7.5.3 Written Research Proposal

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

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

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

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

7.5.4 Oral Examination Format

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

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

- Are the timeline and the scope of the proposed work reasonable?

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

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

7.6 Dissertation Research & Teaching (Years 3 and beyond)

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

7.6.1 PhD Dissertation

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

- Complete at least 30 dissertation credit hours (ASEN 8990) by the time the student defends.
- Comply with the Graduate School's format requirements and specifications.
- Meet all of the Graduate School's deadlines for defense and dissertation submission.

■ 7.6.2 Final Examination

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

- A student must be registered as a regular degree student at CU Boulder for a minimum of five, and no more than ten, dissertation hours the semester in which the final examination is scheduled.
- The examination will be oral and open to anyone who wishes to attend.

- The examination will be conducted by the same dissertation committee in place for the comprehensive exam.
- More than one dissenting vote will disqualify the candidate. In case of failure, the examination may be attempted only one more time. A second failure will result in automatic suspension by the Graduate School. Signatures from all committee members are required.
- Two weeks prior to the exam students submit a copy of the Doctoral Examination Report form listing their committee members to their Graduate Program Advisor. The Doctoral Exam form will be returned to the student after it's approved by the Graduate School.
- The Doctoral Exam form will be returned to the student after approval by the Graduate School. Students will send the Doctoral Examination Report to their committee members via DocuSign to obtain signatures.

8 Appointments

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

- Salary compensation, by semester, with tuition support: Research Assistant (RA) and Teaching Assistant (TA).
- Salary compensation, by semester: Teaching Facilitators (TF).
- Hourly paid positions, for research, grading or other activities in the department.
- Additionally, students can also be supported through external fellowships, or with personal funds.

○ 8.1 Appointment Percentage

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

○ 8.2 Tuition

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

○ 8.3 Appointment Periods

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

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

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

○ 8.4 Leave

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

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

Appendix A. Focus Area Curricula

○ A.1 Astrodynamics and Satellite Navigation Systems (ASN)

ASN Specific MS Requirements

Three ASN Core Classes

One ASEN MS Course or Required course from an outside (non-ASN) AES Focus Area. The outside course is any course not listed under the ASN curriculum.

ASN Specific PhD Requirements

There are no specific course requirements for the PhD in ASN beyond the overall departmental requirements. ASN students must complete prelim questions in two of the four core areas

Core (Required) MS Courses in ASN Focus Area:

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

*ASEN 5050 and 5052: Students may equivalently take either one of these two courses (but not both) to meet the core requirements, prelim exam topics, and/or to satisfy prerequisites for relevant 6000 level astrodynamics courses.

Elective Courses offered by ASN Focus Area:

Course Number	Course Title	Offering
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 6070	Satellite Geodesy	Fall, Biennially
ASEN 6080	Statistical Orbit Determination	Spring, Annually
ASEN 6020	Optimal Trajectories	Fall, Triennially
ASEN 6060	Advanced Astrodynamics	Fall, Triennially
ASEN 6090	Advanced GNSS Software	Spring, Biennially
ASEN 6091	Global Satellite Navigation System (GNSS) Receiver Architecture	Spring, Biennially
ASEN 6519	GNSS for Remote Sensing	Spring, Biennially
ASEN 6519	Celestial Mechanics & Advanced Astrodynamics	Fall, Triennially
ASEN 6519	Multi-Object Detection, Tracking, and Characterization	Fall, Triennially

○ A.1 Autonomous Systems (AUT)

AUT Specific MS Requirements

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

Control Theory

ASEN 5014 Linear Control Systems

ASEN 6024 Nonlinear Systems

Estimation and Sensor Fusion

ASEN 5044 Statistical Estimation for Dynamical Systems

Dynamics and Modeling of Vehicles

ASEN 6519 System Identification for Control

ASEN 5519 Small UAS Dynamics and Control

Autonomous Decision-Making

ASEN 5519 Decision-Making Under Uncertainty

ASEN 5254 Algorithmic Motion Planning

Programming for Embedded Systems

ASEN 5067 Microavionics

MCEN 5115 Mechatronics and Robotics

ECEN 5613 Embedded System Design

ECEN 5813 Principles of Embedded Software

CSCI 5302 Advanced Robotics

AUT Course-only MS Requirements

Satisfaction of AUT Specific MS Requirements, plus two additional courses, each from a *different topic area.

*Note: 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 AUT Focus Area:

Course Number	Course Title	Offering
ASEN 5114	Automatic Control Systems	Fall
ASEN 6519	Cooperative Control	Varies
ASEN 6519	Stochastic Verification and Synthesis	Fall
ASEN 6519	Hybrid Control Systems	Spring
ASEN 5519	Machine Learning for Aerospace	Varies
ASEN 5519/6519	Aerobotics	Spring

Example Elective Courses offered outside AUT Focus Area:

Course Number	Course Title	Offering
CS	Machine Learning	Check with CS
ECEE	Multi-agent Control	Check with ECEE
CS	Convex Optimization	Check with CS
ECEE	Sampled Data Systems	Check with ECEE
CS	Computer Vision	Check with CS
ME	Robust, Multivariable Control	Check with ME

○ A.1 Bioastronautics (BIO)

Bio Specific MS Requirements

ASEN 5016 Space Life Sciences

ASEN 5158 Space Habitat Design

One of four:

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

One of three:

ASEN 5335 Aerospace Environment (RSESS)

ASEN 5050 Space Flight Dynamics (ASN)

ASEN 5053 Rocket Propulsion

Bio Specific PhD Requirements

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

ASEN 5016 Space Life Sciences

ASEN 5158 Space Habitat Design

Required MS Courses in BIO Focus Area:

Course Number	Course Title	Offering
ASEN 5016	Space Life Sciences	Spring, Annually
ASEN 5158	Space Habitat Design	Fall, Annually

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

Course Number	Course Title	Offering
ASEN 5335	Aerospace Environment	Spring, Annually
ASEN 5050†	Space Flight Dynamics	Fall, Annually
ASEN 5053	Rocket Propulsion	Fall

†ASEN 5052: Analytical Astrodynamics is an alternative option to ASEN 5050. ASEN 5052 will satisfy the same requirements and prerequisites as ASEN 5050.

Elective Courses offered by BIO Focus Area:

Course Number	Course Title	Offering
ASEN 5327	Experimental Design and Statistical Methods	Varies
ASEN 6116	Spacecraft Life Support Systems	Varies
ASEN 6316	Extravehicular Activity	Varies
ASEN 6216	Human Operation of Aerospace Vehicles	Varies
ASEN 5226	Medicine in Space and Surface Environments	Spring, Annually
ASEN 5849	MS Independent Study	on request
ASEN 6849	Independent Study (for PhD 'pre/non-thesis' topic)	on request

○ A.1 Fluids, Structures and Materials (FSM)

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

FSM Specific MS Requirements

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

FSM Course-only M.S. Requirements

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

FSM Specific PhD Requirements

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

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

Core Courses Offered by FSM Focus Area:

Fluids:

- ASEN 5051 Fundamentals of Fluid Dynamics (fall offering)
- ASEN 5151 Fundamentals of Gas Dynamics (spring offering)
- ASEN 5519 Molecular Thermo & Kinetics (fall offering)

Structures and Materials:

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

Elective Courses approved by FSM Focus Area:

Fluids

Course Number	Course Title	Offering
ASEN 5053	Rocket Propulsion	Varies
ASEN 5063	Aircraft Propulsion	Fall, Even years
ASEN 5121	Boundary Layers, Convection, and Applied CFD	Spring, Odd years
ASEN 6037	Turbulent Flow	Spring, Annually
ASEN 5519	Introduction to Hypersonics	Fall, Annually
MCEN 5022	Classical Thermodynamics	Spring, Annually
MCEN 5042	Heat Transfer	Spring, Annually
MCEN 5152	Introduction to Combustion	Fall, Annually
MCEN 5151	Flow Visualization	Fall, Annually
MCEN 5228	Computational Fluid Dynamics	Varies
MCEN 6001	Reacting Flows	Spring,Even years
ASEN 6321	Computational Fluid Dynamics Structured Grid	Fall, Even years
ASEN 6331	Computational Fluid Dynamics Unstructured Grid	Fall, Odd years
ASEN 6011	Experimental Fluid Mechanics	Fall, Even years
ASEN 6061	Molecular Gas Dynamics and Direct Monte Carlo Simulation	Varies
ASEN 6519	Advanced Turbulence Simulation	Varies
ASEN 6519	Flow Control	Varies
ASEN 6519	Stabilized and Multiscale Finite Element Methods	Varies
ASEN 6519	Mathematical Foundations of Finite Element Analysis	Varies
ASEN 6519	Isogeometric Analysis	Varies

Structures and Materials

Course Number	Course Title	Offering
ASEN 5111	Aeroelasticity	Varies
ASEN 5148	Spacecraft Design	Spring, Annually
ASEN 5218	Large Space Structures Design	Varies
ASEN 5212	Composite Structures and Materials	Spring
ASEN 5519	Nonlinear Mechanical Vibration	Varies
ASEN 5519	Design Optimization in Aerospace Systems	Spring, Biennially
ASEN 5519	Introduction to Phononics	Fall, Biennially
ASEN 5519	Inverse Methods	Varies
ASEN 5519	Deployable and Lightweight Structures	Varies
ASEN 5188/ Same as EMEN 5405	Space Systems Engineering	Spring
ASEN 6107	Nonlinear Finite Elements	Spring, Biennially
ASEN 6367	Advanced Finite Elements for Plates & Shells	Spring, Biennially
ASEN 6412	Uncertainty Quantification	Spring, Biennially
ASEN 6519	Isogeometric Analysis	Varies
ASEN 6519	Mathematical Foundations of Finite Element Analysis	Varies
ASEN 6519	Molecular Dynamics	Spring, Biennially
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 Mechanics of Solids and Structures	Check with CVEN
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

○ A.1 Remote Sensing, Earth and Space Science (RSESS)

The expected competency at the graduating masters level in the RSESS Focus Area is to have completed coursework in four primary topics of study (1) Data or Numerical Analysis Methods, (2) Instrumentation Fundamentals, (3) Physical Sciences of Earth and Space and (4) Astrodynamics and Satellite Navigation Systems (ASN):

The expected competency at the PhD level is to further advance the four primary topics within RSESS by complementary theory and analysis obtained through coursework offered at the 6000 level and above, and by research activities in developing the PhD thesis. The below requirements are applicable to both MS and PhD candidates in the RSESS Focus Area.

Required courses needed to specialize in the RSESS Focus Area are:

- One 3-credit course in data or numerical analysis methods
- One 3-credit course in instrumentation fundamentals
- One 3-credit course in physical sciences of Earth and Space
- One 3-credit course in astrodynamics or aerospace engineering systems

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

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

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

Course Number	Course Title	Offering
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 5540	Introduction to Time Series	Spring, Biennially
APPM 5580/ STAT 5610	Introduction to Statistical Learning	Spring, Annually
APPM/STAT 5520	Introduction to Mathematical Statistics	Fall, Annually
APPM 5570	Statistical Methods	Fall, Spring Annually

Course Number	Course Title	Offering
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
ECEN 5652	Detection and Extraction of Signals from Noise	Spring, Annually

RSESS Instrumentation Fundamentals Primary Courses (2):

Course Number	Course Title	Offering
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 6365	Lidar Remote Sensing	Varies
ASEN 6265	Fundamentals of Spectroscopy for Optical Remote Sensing	Varies
ASEN 5067	Microavionics	Varies
ASEN 5168	Remote Sensing Instrumentation	Not offered currently

RSESS Physical Sciences Primary Courses (3):

Course Number	Course Title	Offering
ASEN 5335	Aerospace Environment	Spring, Annually
ATOC/ASEN 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

Course Number	Course Title	Offering
ASEN 6519	Special Topics in Aerospace Environment: Upper Atmospheres	Varies

RSESS ASN Primary Courses (4):

Course Number	Course Title	Offering
ASEN 5014	Linear Control 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
ASEN 5044	Statistical Estimation for Dynamical System	Fall and Spring, Annually

†ASEN 5052 is an alternative option to ASEN 5050. ASEN 5052 will satisfy the same requirements and prerequisites as ASEN 5050.

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

RSESS Core Courses:

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

Appendix B. Approved Math Courses

○ B.1 List of *Approved Math Courses

Approved Math Courses
ASEN 5227: Aerospace Math
ASEN 5307: Engineering Data Analysis Methods
ASEN 5417: Numerical Methods for Differential Equations
ASEN 5044: Statistical Estimation for Dynamical Systems (Can be used to meet only one ASEN curriculum-specific requirement, i.e. math or ASN core. This restriction does not apply to certificate requirements)
ASEN 5519: Multi-Object Filtering Theory
ASEN 5327: Experimental Design and Statistical Methods
ASEN 6412: Uncertainty Quantification
EMEN 5005: Intro to Applied Statistical Methods
**APPM 4000, 5000, 6000, 7000 level courses
**MATH 4000, 5000, 6000, 7000 level courses
**STAT 4000, 5000, 6000, 7000 level courses
ECEN 5612: Random Processes for Engineers
ECEN 5632: Theory and Application of Digital Filtering
ECEN 5652: Detection and Extraction of Signals from Noise
CSCI 5636: Numerical Solution of Partial Differential Equations

*Note that any course can be used to meet only one curriculum-specific requirement (i.e., math or Focus Area specific requirements).

**4000 level courses cannot be used towards the PhD Degree. Only MS degrees allow up to 6 credit hours at the 4000 level from approved departments, to count towards the degree.

Appendix C. AES Department Certificates

- Grades of ***B or highe***r are required for fulfillment of requirements and certificate award.
- For degree-seeking students, certificates are awarded at the time of graduation. Review the Academic Calendar for posting and mailing dates.
- Request certificate enrollment and awarding in our Certificates page.
- Continuing Education students: Please revise our Continuing Education and Certificates page for enrollment and other information.

○ C.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).

Core Requirements* (12 credit hours):

ASEN 5010 - Spacecraft Attitude Dynamics and Control

ASEN 5050 – Astrodynamics or ASEN 5052 Analytical Astrodynamics

ASEN 5044** - Statistical Estimation for Dynamical Systems

ASEN 5090 - Introduction to Global Navigation Satellite Systems

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

** Taking ASEN5044 as part of the certificate requirement does not preclude it counting as a math course to satisfy the MS or PhD requirement.

Advanced Requirements (6 credit hours):

Select ANY two 6000 level courses in ASN including, but not limited to, the ASN Electives listed in Appendix A.1 and any ASEN 6519 special topics courses offered by faculty in the ASN Focus Area.

○ C.2 Certificate in Hypersonics (Open to continuing educations students)

Certificate Requirements

The standard requirements of this certificate program are the completion of twelve (12) hours of graduate-level coursework (typically four 3-credit courses) with grades of B or better in each course. There is one required course, ASEN 5519 Introduction to Hypersonics. Each student is free to choose the other three courses from the elective list below.

Students also pursuing other graduate certificates cannot use the same courses to count for both certificates.

▪ Requirements

- ASEN 5519: Introduction to Hypersonics
- Three additional 3-credit courses from the list of *Electives*.

▪ Electives

- ASEN 5151: Fundamentals of Gas Dynamics
- MCEN 5042: Heat Transfer
- MCEN 6001: Reacting Flows
- MCEN 5228: High Temperature Materials
- MCEN 5022: Classical Thermodynamics
- ASEN 5053: Rocket Propulsion
- ASEN 5331: CFD Unstructured Grid
- ASEN 6061: Molecular gas Dynamics and DSMC
- ASEN 5037/MCEN 7221: Turbulent Flows
- MCEN 5024: Materials Chemistry and Structure
- ASEN 6015: Aerospace Vehicle Guidance and Control
- ASEN 5152: High Temperature Gas Dynamics
- ASEN 5519: Molecular Thermo & Kinetics
- ASEN 5018: Graduate Projects (Specifically focused on hypersonics, approved by certificate coordinator)

○ C.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. The program is open to new and current degree-seeking AES and ECEE students. Non-degree students cannot enroll in this program.

Six courses total (18 credit hours)

- **Certificate Requirements**

Four Required Courses (12 credit hours)

*ECEN 5134 Antennas (for space applications) – 3 credit hour ***or*** ECEN5104 RF Passive/Active Circuits – 3 credit hours

*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 RF Lab – 3 credit hours
ASEN 5090 GPS – 3 credit hours
Either (a) or (b) below, depending on major;

(a) ASEN 5148 Spacecraft Design – 3 credit hours (required for ECEE majors)
(b) ECEN 3410 Electromagnetic Waves and Transmission – 3 credit hours (required for AES majors)

Two Elective Courses – Students choose 2 out of 5 (6 credit hours total)

ECEN 5134 Antennas (for space applications) – 3 credit hours *or* ECEN5104 RF Passive/Active Circuits (fall) – 3 credit hours (*whichever not taken as a requirement*)

ECEN 5114 Waveguides – 3 credit hours

ECEN 5154 Computational EM – 3 credit hours

ASEN 5245 Radar Remote Sensing – 3 credit hours

AES Grad projects (ASEN 5018 or ASEN 6028) – 3 credit hours (*Approved RF related project can only count for 1 elective)*

○ C.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

- Four courses are required totaling at least 12 credit hours, with grades of B or better.
  - Two courses from one of the following topical areas (6 credit hours):
    - Data Analysis
    - Instrumentation and Measurement Techniques
    - Remote Sensing Theory
  - One course in each of the two remaining topical areas (6 credit hours)
  - In addition, one semester (1 credit hour) of Remote Sensing Seminar (Co-listed as ASEN 5210 / ATOC 7500)

13 credit hours total

Data Analysis Courses:

ASEN 5307 Engineering Data Analysis

ASEN 6337 Remote Sensing Data Analysis

ASTR 5550 Observations, Data Analysis, and Statistics

ECEN 5004 Environmental Signal Processing

ECEN 5254 Remote Sensing Signals and Systems

ECEN 5612 Random Processes for Engineers

ECEN 5652 Detection and Extraction of Signals from Noise

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

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

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

○ C.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 will allow

students to develop interdisciplinary skills in the area of satellite design, making them more desirable to future employers.

■ Certificate Requirements

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

ASEN 5148 – Spacecraft Design* (3 credit hours)

ASEN 5018 and 6028 – Graduate Projects (6 credit hours) - Projects must have a satellite or rocket focus.

1 course from elective list (3 credit hours)

12 credit hours total

Track 2: Distance Compatible Track

ASEN 5148 – Spacecraft Design* (3 credit hours)

EMEN 5405 – Fundamentals of System Engineering* (3 credit hours)

2 courses from elective list (no more than one EMEN course) (6 credit hours)

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

12 credit hours total

Elective list[1]

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

ASEN 5050 – Space Flight Mechanics*†

ASEN 5053 – Rocket and Spacecraft Propulsion

ASEN 5090 – Introduction to Global Navigation Satellite Systems*

ASEN 5335 – Aerospace Environment*

ASEN 5067 – Microavionics [3]

ECEN 5134 – Electromagnetic Radiation and Antennas*

ECEN 5264 – Electromagnetic Absorption, Scattering and Propagation*

ECEN 5517 – Photovoltaic Power Electronics Laboratory

ECEN 5613 – Embedded System Design

ECEN 5623 – Real-Time Embedded Systems

ECEN 5634 – Graduate Microwave and RF Laboratory

ECEN 5692 – Principles of Digital Communications

ECEN 5797 – Introduction to Power Electronics*

ECEN 5813 – Principles of Embedded Software

EMEN 5010 – Introduction to Engineering Management*

EMEN 5030 – Fundamentals of Project Management*

EMEN 5031 – Software Project Management*

EMEN 5405 – Fundamentals of System Engineering*

1: Students are required to meet course prerequisites. Questions should be directed to the course instructor.
2: Core ASN certificate courses. Cannot be counted for both certificates.
3: Course enrollment is limited to non-Electrical Engineering students.
* Courses available via distance.
† ASEN 5052 is an alternative option to ASEN 5050. ASEN 5052 will satisfy the same requirements and prerequisites as ASEN 5050.

○ C.6 Certificate in Space Weather and Applications (Open to continuing educations students)

This certificate will provide you with interdisciplinary skills in the field of space weather of both fundamental processes in science and practical applications to space-based and ground-based technology.

- Requirements

ASEN 5335: Aerospace Environment (3 credit hours)

Two courses from the Tier 1 Electives List (6 credit hours)

One additional course from the Tier 2 Electives list (3 credit hours)

*At least one course must be outside the student's home department

12 credit hours total

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  - **Tier 1 Foundational Elective list**

ASEN 6050: Space Instrumentation (equiv. to ASTR 6050)

ASEN 6365: Lidar Remote Sensing

ASTR 5140: Astrophysical and Space Plasmas (equiv. to PHYS 5141)

ASTR 5300: Introduction to Magnetospheres

ASTR 5150: Introductory Plasma Physics (equiv. to PHYS 5150)

ATOC 5050: Introduction to Atmospheric Dynamics

ATOC 5235: Introduction to Atmospheric Radiative Transfer and Remote Sensing (equiv. to ASEN 5235)

  - **Tier 2 Concentration/Focus Elective list**

Applications

ASEN 5090: Introduction to Global Navigation Satellite Systems

ASEN 5016: Space Life Sciences

ASEN 6265: Fundamentals of Spectroscopy for Optical Remote Sensing

Design & Instrumentation

ASEN 5158: Space Habitat Design

ASEN 5168: Remote Sensing Instrumentation Design

ASEN 5440: Mission Design and Development for Space Sciences (equiv. to ASTR 5780)

Radiative Processes & Atmosphere Coupling

ASTR 5120: Radiative and Dynamical Processes

ASTR 5810: Planetary Atmospheres (equiv. to ATOC 5810 & GEOL 5810)

ATOC 5560: Radiative Processes in Planetary Atmospheres (equiv. to ASTR 5560)

Electromagnetics & Plasma

ASTR 7160: Intermediate Plasma Physics (equiv. to PHYS 7160)

Data Science

APPM 5580: Statistical Learning

ASEN 6050: Data Assimilation and Inverse Methods for Earth and Geospace

APPM 5250: Data Assimilation in High Dimensional Dynamical Systems (equiv. to STAT 5250/5510)

Selected Topics

ASEN 5519/6519: Selected Topics (Note: Special Topics courses taken for the certificate must have a space weather association, determined and approved before the semester the course is taken. Please contact the graduate certificate advisor for approval.)

ASTR 5830: Topics in Planetary Science (equiv. to ATOC 5830 & GEOL 5830)

ASTR 7500: Special Topics in Astrophysical & Planetary Sciences

ATOC 7500: Special Topics in Atmospheric and Oceanic Sciences

○

Appendix D. List of Approved Certificates

○ D.1 Interdisciplinary Certificates

Some of the most popular certificate programs include the following.

- Astrodynamics and Satellite Navigation
- Atmospheric & Oceanic Sciences
- Environment, Policy and Society
- Oceanography

- Satellite System Design
- Remote Sensing (Modified for RSESS MS students)

○ D.2 Professional Certificates

Electrical and Computer Engineering:

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

Engineering Management:

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

Telecommunications:

- Computer and Network Security
- Power Electronics
- Software Engineering

○ D.3 Certificates Requiring Pre-Approval

Interdisciplinary Certificates

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

Appendix E. Approved List of Prelim Courses

Astrodynamics and Satellite Navigation Systems (ASN)

· ASEN5050 or 5052 (not both)

· ASEN5010

· ASEN5090

· ASEN5044*

* Cannot count as an out-of-area topic for ASN.

Autonomous Systems (AUT)

· ASEN 5014

· ASEN 5044*

· ASEN 5254

· ASEN 5519 (Decision Making Under Uncertainty)

* Cannot count as an out-of-area topic for AUT.

Bioastronautics (BIO)*

· ASEN 5158

· ASEN 5016

* Only 2 options – you must take these two

Fluids, Structures and Materials (FSM)*

Fluids	**Structures**
ASEN 5051	ASEN 5007
ASEN 5519: Molecular Thermo & Kinetics	ASEN 5012
ASEN 5151	ASEN 5022

*Note: Fluids and structures are treated as separate focus areas for the prelim, thus a student can take their two focus area core from one track (i.e. fluids) and the third out of focus core from the other track (i.e.

structures). See page 29 in AY20-21 Grad handbook.

Remote Sensing, Earth and Space Science (RSESS)

- ASEN 5245
- ASEN 5307
- ASEN 5335