AEROSPACE ENGINEERING SCIENCES - MASTER OF SCIENCE (MS)

CU Boulder's Department of Aerospace Engineering Sciences (AES) is internationally recognized for its research and education leadership in aerospace engineering, Earth and space sciences. Its world-renowned engineers and scientists tackle challenges in aerospace technology and science, focusing on Astrodynamics and Satellite Navigation Systems (ASN); Autonomous Systems (AUT); Bioastronautics (BIO), Fluids, Structures and Materials (FSM); and Remote Sensing, Earth and Space Science (RSESS).

With more than 50 faculty members and over 550 MS and PhD students, our graduate programs prepare aerospace engineering students to meet the needs of our 21st-century society through the understanding, conception, design and application of aerial and spacecraft systems.

In the MS program we focus on hands-on, experiential learning, technical and organizational expertise, and end-to-end mission and systems perspectives via course-based degree options.

Research opportunities for MS students are very limited and are not funded. Students interested in completing an MS thesis are encouraged to take a few of our courses before deciding to pursue that route.

For more information, visit the department's Prospective Graduate Students webpage and our Graduate Student Handbook.

Requirements

Program Requirements

Students must complete a total of 30 credit hours, equivalent to 10 classes, with a grade of B- or better and a cumulative GPA of at least 3.00. Of these 30 credits, at least 24 credit hours must be completed at the 5000 level or above, and at least 18 of those credits must be in Aerospace Engineering (ASEN) courses, and one approved math course. (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class. Seminar credits, even those earned in other disciplines, do not count toward the MS degree.)

Up to 6 credits can be taken at the 4000 level in approved engineering, math and science departments (ECEN, CVEN, MCEN, CHEN, CSCI, ATOC, ASTR, PHYS, MCDP, APPM, MATH, STAT, CHEM, IPHY, GEOL, ENVD).

ASEN courses level 4000 or below do not count towards AES graduate degrees.

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.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>ASEN 5044</td>
<td>Statistical Estimation for Dynamical Systems 1</td>
<td></td>
</tr>
<tr>
<td>ASEN 5227</td>
<td>Mathematics for Aerospace Engineering Sciences 1</td>
<td></td>
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<tr>
<td>ASEN 5307</td>
<td>Engineering Data Analysis Methods</td>
<td></td>
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<tr>
<td>ASEN 5417</td>
<td>Numerical Methods in Engineering and Science</td>
<td></td>
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<tr>
<td>ASEN 5519</td>
<td>Special Topics (Multi-Object Filtering Theory)</td>
<td></td>
</tr>
<tr>
<td>ASEN 5519</td>
<td>Special Topics (Experimental Design and Statistical Methods)</td>
<td></td>
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<tr>
<td>ASEN 6412</td>
<td>Uncertainty Quantification</td>
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<tr>
<td>EMEN 5005</td>
<td>Introduction to Applied Statistical Methods</td>
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<tr>
<td>ECEN 5612</td>
<td>Random Processes for Engineers</td>
<td></td>
</tr>
<tr>
<td>ECEN 5632</td>
<td>Theory and Application of Digital Filtering</td>
<td></td>
</tr>
<tr>
<td>ECEN 5652</td>
<td>Detection and Extraction of Signals from Noise</td>
<td></td>
</tr>
<tr>
<td>4000, 5000, 6000, or 7000 level APPM course</td>
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<tr>
<td>4000, 5000, 6000, or 7000 level MATH course</td>
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<tr>
<td>4000, 5000, 6000, or 7000 level STAT course</td>
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Choose one of the following:

Thesis Option

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

ASEN 6950 Master's Thesis

Non-Thesis Option (Select One)

ASEN 5018 Graduate Projects I
& ASEN 6028 and Graduate Projects II (6 credits)

Required courses leading to an approved certificate (or completion of the dual ASEN/EMP degree)

Course-only option (FSM and AUT)

1 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.

Please visit our Graduate Student Handbook for focus area requirements and coursework offerings. Also, visit our website for syllabi and tentative future schedules.

Time Limit

All degree requirements must be completed within four years of the date of commencing coursework. Most students complete the degree in one to two years.


Requirements of the MS degree in the Astrodynamics and Satellite Navigation Systems focus area are:
Aerospace Engineering Sciences - Master of Science (MS)

- Three ASN Core Classes
- One ASEN MS Course or Required course from an outside (non-ASN) AES focus area

### Core Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>ASEN 5010</td>
<td>Spacecraft Attitude Dynamics and Control</td>
<td></td>
</tr>
<tr>
<td>ASEN 5044</td>
<td>Statistical Estimation for Dynamical Systems</td>
<td></td>
</tr>
<tr>
<td>ASEN 5050 or ASEN 5052</td>
<td>Space Flight Dynamics or Analytical Astrodynamics</td>
<td></td>
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<tr>
<td>ASEN 5090</td>
<td>Introduction to Global Navigation Satellite Systems</td>
<td></td>
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</table>

### Additional Course

Choose one ASEN MS Course or Required course from an outside (non-ASN) AES focus area

### Elective Courses Offered by ASN Focus Area

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>ASEN 6008</td>
<td>Interplanetary Mission Design</td>
<td></td>
</tr>
<tr>
<td>ASEN 6010</td>
<td>Advanced Spacecraft Dynamics and Control</td>
<td></td>
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<tr>
<td>ASEN 6014</td>
<td>Spacecraft Formation Flying</td>
<td></td>
</tr>
<tr>
<td>ASEN 6015</td>
<td>Space Vehicle Guidance and Control</td>
<td></td>
</tr>
<tr>
<td>ASEN 6020</td>
<td>Optimal Trajectories</td>
<td></td>
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<tr>
<td>ASEN 6060</td>
<td>Advanced Astrodynamics</td>
<td></td>
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<tr>
<td>ASEN 6070</td>
<td>Satellite Geodesy</td>
<td></td>
</tr>
<tr>
<td>ASEN 6080</td>
<td>Statistical Orbit Determination</td>
<td></td>
</tr>
<tr>
<td>ASEN 6091</td>
<td>Global Navigation Satellite System (GNSS) Receiver Architecture</td>
<td></td>
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<tr>
<td>ASEN 6519</td>
<td>Special Topics (GNSS for Remote Sensing)</td>
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<tr>
<td>ASEN 6519</td>
<td>Special Topics (Celestial Mechanics &amp; Advanced Astrodynamics)</td>
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<tr>
<td>ASEN 6519</td>
<td>Special Topics (Multi-Object Detection, Tracking, and Characterization)</td>
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### Autonomous Decision-Making

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<tr>
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<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>ASEN 5519</td>
<td>Special Topics (Decision-Making Under Uncertainty)</td>
<td></td>
</tr>
<tr>
<td>ASEN 5519</td>
<td>Special Topics (Algorithmic Motion Planning)</td>
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### Programming for Embedded Systems

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<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>ASEN 5067</td>
<td>Microavionics: Introduction to PIC Microcontrollers for Aerospace Systems</td>
<td></td>
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<tr>
<td>MCEN 5115</td>
<td>Mechatronics and Robotics I</td>
<td></td>
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<tr>
<td>ECEN 5613</td>
<td>Embedded System Design</td>
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<tr>
<td>ECEN 5813</td>
<td>Principles of Embedded Software</td>
<td></td>
</tr>
<tr>
<td>CSCI 5302</td>
<td>Advanced Robotics</td>
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</tbody>
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### Elective Courses Offered by AUT Focus Area

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>ASEN 5114</td>
<td>Automatic Control Systems</td>
<td></td>
</tr>
<tr>
<td>ASEN 5519</td>
<td>Special Topics (Machine Learning for Aerospace)</td>
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</tr>
<tr>
<td>ASEN 5519</td>
<td>Special Topics (Aerobotics)</td>
<td></td>
</tr>
<tr>
<td>ASEN 6519</td>
<td>Special Topics (Cooperative Control)</td>
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</tr>
<tr>
<td>ASEN 6519</td>
<td>Special Topics (Stochastic Verification and Synthesis)</td>
<td></td>
</tr>
<tr>
<td>ASEN 6519</td>
<td>Special Topics (Hybrid Control Systems)</td>
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</tbody>
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### Bioastronautics (BIO)

Students are required to take two Core courses and one course from each of the following areas:

- Core Courses
  - ASEN 5016 Space Life Sciences
  - ASEN 5158 Space Habitat Design
  - Choose one:
    - ASEN 5226 Medicine in Space and Surface Environments
    - ASEN 5616 Spacecraft Life Support Systems
    - ASEN 6216 Human Operation of Aerospace Vehicles
    - ASEN 6519 Special Topics (Extravehicular Activity)

- Elective Courses Offered by BIO Focus Area
  - ASEN 5519 Special Topics (Experimental Design and Statistical Methods)
  - ASEN 6116 Spacecraft Life Support Systems
  - ASEN 6519 Special Topics (Extravehicular Activity)
  - ASEN 6216 Human Operation of Aerospace Vehicles
  - ASEN 5226 Medicine in Space and Surface Environments
  - ASEN 5849 Independent Study (for MS students)
Fluids, Structures and Materials (FSM) (https://www.colorado.edu/aerospace/academics/graduates/curriculum/fluids-structures-and-materials/)

Requirements of the MS degree in the Fluids, Structures and Materials (FSM) focus area are:

- Two Core Classes in your chosen 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. (See Graduate Handbook for detailed listing.)
- Attending 50% of the “Fluid, Structures and Materials” seminars each semester.

### Core Courses

**Fluids Sub-Track**

- ASEN 5051 Fundamentals of Fluid Dynamics
- ASEN 5151 Fundamentals of Gas Dynamics
- ASEN 5519 Special Topics (Molecular Thermodynamics and Kinetics)

**Structures and Materials Sub-Track**

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

### Elective Courses Approved by FSM Focus Area

**Fluids**

- ASEN 5053 Rocket and Spacecraft Propulsion
- ASEN 5063 Aircraft Propulsion
- ASEN 5121 Boundary Layers and Convection
- ASEN 5519 Special Topics (Introduction to Hypersonics)
- ASEN 5321 Computational Fluid Dynamics Structured Grid
- ASEN 5331 Computational Fluid Dynamics Unstructured Grid
- ASEN 6011 Experimental Fluid Mechanics
- ASEN 6061 Molecular Gas Dynamics and DSMC
- ASEN 6519 Special Topics (Advanced Turbulence Simulation)
- ASEN 6519 Special Topics (Flow Control)
- ASEN 6519 Special Topics (Stabilized and Multiscale Finite Element Methods)
- ASEN 6519 Special Topics (Mathematical Foundations of Finite Element Analysis)
- ASEN 6519 Special Topics (Isogeometric Analysis)
- MCEN 5022 Classical Thermodynamics
- MCEN 5042 Heat Transfer
- MCEN 5151 Flow Visualization
- MCEN 5152 Introduction to Combustion
- MCEN 6001 Reacting Flows

**Structures and Materials**

- ASEN 5111 Introduction to Aeroelasticity
- ASEN 5148 Spacecraft Design
- ASEN 5188 Fundamentals of Systems Engineering
- ASEN 5218 Large Space Structures Design
- ASEN 5519 Special Topics (Design Optimization in Aerospace Systems)
- ASEN 5519 Special Topics (Introduction to Phononics)
- ASEN 5519 Special Topics (Inverse Methods)
- ASEN 5519 Special Topics (Deployable and Lightweight Structures)
- ASEN 6107 Nonlinear Finite Element Methods
- ASEN 6367 Advanced Finite Element Methods for Plates, Shells, and Solids
- ASEN 6412 Uncertainty Quantification
- ASEN 6519 Special Topics (Isogeometric Analysis)
- ASEN 6519 Special Topics (Mathematical Foundations of Finite Element Analysis)
- ASEN 6519 Special Topics (Molecular Dynamics)
- CVEN 5161 Advanced Mechanics of Materials I
- CVEN 6161 Advanced Mechanics of Materials II
- CVEN 7141 Plates and Shells
- CVEN 7511 Computational Finite Inelasticity and Multiphase Mechanics
- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5228 Special Topics in Mechanical Engineering (Machinics of Composite Materials)
- MCEN 5228 Special Topics in Mechanical Engineering (Machinics of Soft Materials)

Remote Sensing, Earth and Space Science (RSESS) (https://www.colorado.edu/aerospace/current-students/graduates/curriculum/remote-sensing-earth-space-sciences/)

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.

### Data or Numerical Analysis Methods Primary Courses

Choose one:

- ASEN 5307 Engineering Data Analysis Methods
- ASEN 6055 Data Assimilation & Inverse Methods for Earth & Geospace Observations
- ASEN 6337 Remote Sensing Data Analysis
- APPM 5350 Methods in Applied Mathematics: Fourier Series and Boundary Value Problems
- APPM 5580/STAT 5610 Introduction to Statistical Learning
- APPM 5570 Statistical Methods
- ECEN 5612 Random Processes for Engineers
- ECEN 5632 Theory and Application of Digital Filtering
- ECEN 5652 Detection and Extraction of Signals from Noise
### Instrumentation Fundamentals Primary Courses
Choose one: 3
- ASEN 5067 Microavionics: Introduction to PIC Microcontrollers for Aerospace Systems
- ASEN 5090 Introduction to Global Navigation Satellite Systems
- ASEN 5168 Remote Sensing Instrumentation Design
- ASEN 5245 Radar and Remote Sensing
- ASEN 5440 Mission Design and Development for Space Sciences
- ASEN 6050 Space Instrumentation
- ASEN 6265 Fundamentals of Spectroscopy for Optical Remote Sensing
- ASEN 6365 Lidar Remote Sensing

### Physical Sciences of Earth and Space Primary Courses
Choose one: 3
- ASEN/ATOC 5235 Introduction to Atmospheric Radiative Transfer and Remote Sensing
- ASEN 5335 Aerospace Environment
- ASEN 6519 Special Topics (Aerospace Environment: Upper Atmospheres)
- ASTR 5300 Introduction to Magnetospheres
- ATOC 5050 Atmospheric Thermodynamics and Dynamics
- ATOC 5051 Introduction to Physical Oceanography
- ATOC 5060 Dynamics of the Atmosphere and Oceans
- PHYS 5141 Astrophysical and Space Plasmas
- PHYS 5150 Introductory Plasma Physics

### Astrodynamics and Satellite Navigation Systems
Choose one: 3
- ASEN 5014 Linear Control Systems
- ASEN 5044 Statistical Estimation for Dynamical Systems
- ASEN 5050 Space Flight Dynamics
  or ASEN 5052 Analytical Astrodynamics
- ASEN 5051 Fundamentals of Fluid Dynamics
- ASEN 5148 Spacecraft Design
- ASEN 6070 Satellite Geodesy

Total Credit Hours 12

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### Dual Degree Program
**MS in Aerospace Engineering Sciences and ME in Engineering Management**

Students may complement their aerospace engineering master’s degree with a Master of Engineering (ME) in Engineering Management. To complete the Aerospace Engineering and Engineering Management dual degree program, students must be admitted to Aerospace Engineering first, and apply to Engineering Management afterwards.

**Requirements**
The dual degree consists of 45 credits: 24 credits based on Aerospace Engineering requirements and 21 based on Engineering Management requirements, as detailed below.

For more information, visit the Engineering Management Program’s MS Aerospace Engineering Sciences & ME Engineering Management (http://www.colorado.edu/emp/programs/graduate-program/dual-degree-program/ms-aerospace-engineering-sciences-me-engineering/) webpage.

### Aerospace Engineering
At least 24 credits at the 5000 level or above:
- At least 18 credits in Aerospace Engineering (ASEN) courses.
  (Note: EMEN 5405 Fundamentals of Systems Engineering counts as an ASEN class).
- One approved math course (3 credits)  
- Professional MS students do not follow focus area-specific requirements and do not require the completion of a certificate, graduate projects or MS thesis
- Traditional MS students:
  - Completion of an approved certificate, graduate projects (6 credits) or MS thesis (6 MS thesis credits)
  - Fulfill focus area-specific requirements

Review our Graduate Student Handbook (https://www.colorado.edu/aerospace/current-students/graduates/curriculum/graduate-student-handbooks/) for details on focus area requirements, GPA and grade minimums, and other information.

### Engineering Management
Students must complete at least 21 credits. Visit the Engineering Management website (https://www.colorado.edu/emp/current-students/graduate-programs/dual-graduate-degree/) for details.