AEROSPACE ENGINEERING SCIENCES

The aerospace engineering program is organized around focus areas in astrodynamics and satellite navigation systems, bioastronautics, remote sensing, Earth and space sciences and aerospace engineering systems, including fluid dynamics and propulsion, automatic control, structures and mechanics of materials.

The Ann and HJ Smead Department of Aerospace Engineering Sciences (http://www.colorado.edu/aerospace/) at the University of Colorado Boulder is one of the top aerospace engineering departments in the nation. Aerospace engineers work on Earth and in space not only to extend frontiers, but also to better understand and preserve our terrestrial environment. Few fields offer as many exciting and diverse career opportunities: becoming an astronaut (15 graduates to date have become astronauts), designing the next generation of aircraft and spacecraft, monitoring our global habitat via remote sensing from space, *in situ* sensing with unmanned vehicles and helping to develop environmentally clean energy and transportation systems.

Aerospace graduate students often formulate degree plans on the basis of their interests and needs. Portions of the program are designed to promote our students' engineering and professional development.

Graduate students are admitted into a specific focus area that provides research advising and financial support, and sets specialized admission and program requirements with recommendations for coursework within and outside the department.

The five focus areas are:

- Astrodynamics and Satellite Navigation Systems
- Autonomous Systems
- Bioastronautics
- Fluids, Structures and Materials
- Remote Sensing, Earth and Space Sciences

Each focus area has defined the required characteristics of its successful graduates at the MS and PhD level, and defined the required and elective courses that support its educational program.

Aerospace-related research centers in the College include the Colorado Center for Astrodynamics Research, Aerospace Mechanics Research Center, the Research and Engineering Center for Unmanned Vehicles, and BioServe Space Technologies. Other research centers and institutes within the University that are involved in aerospace-related research activities are the Center for Astrophysics and Space Astronomy (CASA), the Cooperative Institute for Research in Environmental Sciences (CIRES), the Earth Science & Observation Center (ESOC), JILA, and the Laboratory for Atmospheric and Space Physics (LASP).

Course code for this program is ASEN.

Master's Degrees

- Aerospace Engineering Sciences - Master of Science (MS) (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/aerospace-engineering-sciences-master-science-ms/)
- Aerospace Engineering Sciences - Professional Master of Science (MSAES) (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/aerospace-engineering-sciences-professional-master-science-msaes/)

Doctoral Degree

- Aerospace Engineering Sciences - Doctor of Philosophy (PhD) (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/aerospace-engineering-sciences-doctor-philosophy-phd/)

Certificates

- Astrodynamics and Satellite Navigation Systems - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/astrodynamics-satellite-navigation-systems-graduate-certificate/)
- Engineering Management in the Aerospace Industry - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/engineering-management/engineering-management-aerospace-industry-graduate-certificate/)
- Hypersonics - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/hypersonics-graduate-certificate/)
- Radio Frequency Engineering for Aerospace - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/radio-frequency-engineering-aerospace-graduate-certificate/)
- Remote Sensing - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/aerospace-engineering-sciences/remote-sensing-graduate-certificate/)
- Satellite Systems Design - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/interdisciplinary-programs/satellite-system-design-certificate/)
- Space Weather and Applications - Graduate Certificate (https://catalog.colorado.edu/graduate/colleges-schools/interdisciplinary-programs/space-weather-applications-graduate-certificate/)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Ahmed, Nisar R. (https://experts.colorado.edu/display/fisid_153237/)
Associate Professor; PhD, Cornell University

Akos, Dennis M. (https://experts.colorado.edu/display/fisid_131119/)
Professor; PhD, Ohio University

Ali, Hisham (https://experts.colorado.edu/display/fisid_168718/)
Assistant Professor; PhD, Georgia Institute of Technology

Argrow, Brian M. (https://experts.colorado.edu/display/fisid_102860/)
Distinguished Professor; PhD, University of Oklahoma

Arquilla, Katya (https://experts.colorado.edu/display/fisid_173943/)
Assistant Professor; PhD, University of Colorado

Axelrad, Penina (https://experts.colorado.edu/display/fisid_100792/)
Distinguished Professor, Endowed/Named Professor; PhD, Stanford University

Bosanac, Natasha (https://experts.colorado.edu/display/fisid_158199/)
Assistant Professor; PhD, Purdue University

Boyd, Iain (https://experts.colorado.edu/display/fisid_165828/)
Professor, Director; PhD, University of Southampton (England)

Brasseur, James G. (https://experts.colorado.edu/display/fisid_156801/)
Research Professor; PhD, Stanford University

Chu, Xinzhao (https://experts.colorado.edu/display/fisid_141893/)
Professor; PhD, Peking University (China)

Clark, Torin K. (https://experts.colorado.edu/display/fisid_155959/)
Associate Professor; PhD, Massachusetts Institute of Technology

Constantine, Paul
Assistant Professor; PhD, Stanford University

Correll, Nikolaus J. (https://experts.colorado.edu/display/fisid_147555/)
Associate Professor; PhD, Ecole Polytech Federale de Lausanne (Switzerland)

Culp, Robert D.
Professor Emeritus; PhD, University of Colorado Boulder

Doostan, Alireza (https://experts.colorado.edu/display/fisid_147382/)
Professor, Faculty Fellow; PhD, Johns Hopkins University

Emery, William J. (https://experts.colorado.edu/display/fisid_106038/)
Professor Emeritus; PhD, University of Hawaii

Evans, John A. (https://experts.colorado.edu/display/fisid_152970/)
Associate Professor, Associate Chair; PhD, University of Texas at Austin

Farnsworth, John A. (https://experts.colorado.edu/display/fisid_153255/)
Associate Professor; PhD, Rensselaer Polytechnic Institute

Felippa, Carlos A. (https://experts.colorado.edu/display/fisid_105701/)
Professor Emeritus; PhD, University of California, Berkeley

Forbes, Jeffrey M. (https://experts.colorado.edu/display/fisid_100264/)
Professor Emeritus, Research Professor; PhD, Harvard University

Frew, Eric W. (https://experts.colorado.edu/display/fisid_134685/)
Professor, Associate Chair; PhD, Stanford University

Gates, Harvey
Associate Professor Adjunct; PhD, University of Denver

Gerren, Donna S. (https://experts.colorado.edu/display/fisid_108563/)
Teaching Professor Emerita; PhD, University of Kansas

Ghobadi-Far, Khosro (https://experts.colorado.edu/display/fisid_174031/)
Assistant Professor; PhD, University of Newcastle

Glusman, F. Jeff (https://experts.colorado.edu/display/fisid_172040/)
Teaching Assistant Professor; PhD, University of Colorado Boulder

Gremban, Keith (https://experts.colorado.edu/display/fisid_166519/)
Research Professor; PhD, Carnegie Mellon University

Hamlington, Peter Edward (https://experts.colorado.edu/display/fisid_149800/)
Associate Professor; PhD, University of Michigan Ann Arbor

Hayman, Allison P. (https://experts.colorado.edu/display/fisid_156275/)
Assistant Professor

Heckman, Christoffer (https://experts.colorado.edu/display/fisid_155294/)
Assistant Professor; PhD, Cornell University

Hodgkinson, Robert F. (https://experts.colorado.edu/display/fisid_153274/)
Teaching Assistant Professor; MS, University of Colorado Boulder

Holzinger, Marcus J. (https://experts.colorado.edu/display/fisid_164054/)
Associate Professor; PhD, University of Colorado Boulder

Humbert, J. Sean (https://experts.colorado.edu/display/fisid_156202/)
Professor; PhD, California Institute of Technology

Hussein, Mahmoud I. (https://experts.colorado.edu/display/fisid_144300/)
Professor; PhD, University of Michigan Ann Arbor

Jansen, Kenneth E. (https://experts.colorado.edu/display/fisid_147360/)
Professor; PhD, Stanford University

Kantha, Lakshmi H. (https://experts.colorado.edu/display/fisid_100231/)
Professor Emeritus; PhD, Massachusetts Institute of Technology

Klaus, David M. (https://experts.colorado.edu/display/fisid_107103/)
Professor; PhD, University of Colorado Boulder

Knipp, Delores Jane (https://experts.colorado.edu/display/fisid_147655/)
Research Professor; PhD, University of California, Los Angeles

Knudsen, Erik (https://experts.colorado.edu/display/fisid_172046/)
Teaching Assistant Professor, Associate Chair; PhD, University of Florida

Koehler, Chris J. (https://experts.colorado.edu/display/fisid_102226/)
Teaching Associate Professor; MS, University of Colorado Boulder

Koster, Jean N.
Professor Emeritus; PhD, Karlsruher Institut für Technologie (Germany)

Kubitschek, Daniel (https://experts.colorado.edu/display/fisid_144283/)
Lecturer; PhD, University of Colorado Boulder

Lahijanian, Morteza Mehdi (https://experts.colorado.edu/display/fisid_164179/)
Assistant Professor; PhD, Boston University

Larson, Kristine M.
Professor Emerita; PhD, Scripps Institution of Oceanography

Lawrence, Dale A. (https://experts.colorado.edu/display/fisid_104057/)
Professor; PhD, Cornell University

Le Moine, Alexandra
Teaching Assistant Professor; MS, University of Wisconsin

Leben, Robert R.
Research Professor Emeritus; PhD, University of Colorado Boulder

Li, Xinlin (https://experts.colorado.edu/display/fisid_100016/)
Professor; PhD, Dartmouth College

Liu, Hanli
Associate Professor Adjunct; PhD, University of Michigan

Lopez Jimenez, Francisco (https://experts.colorado.edu/display/fisid_157867/)
Assistant Professor; PhD, California Institute of Technology

Macdonald, Robyn (https://experts.colorado.edu/display/fisid_165823/)
Assistant Professor; PhD, University of Illinois at Urbana-Champaign

Mah, John K. (https://experts.colorado.edu/display/fisid_164214/)
Teaching Assistant Professor; MS, Stanford University

Marshall, David B. (https://experts.colorado.edu/display/fisid_158629/)
Research Professor; PhD, Monash University (Australia)

Marshall, Robert A. (https://experts.colorado.edu/display/fisid_155957/)
Associate Professor, Associate Chair; PhD, Stanford University

Maslanik, James
Research Professor Emeritus

Matsuo, Tomoko (https://experts.colorado.edu/display/fisid_145041/)
Associate Professor; PhD, SUNY at Stony Brook

Maute, Kurt (https://experts.colorado.edu/display/fisid_113875/)
Professor, Associate Dean; PhD, University of Stuttgart (Germany)

McGrath, Michael T.
Professor Adjunct; BS, University of Colorado Boulder

McMahon, Jay W. (https://experts.colorado.edu/display/fisid_150062/)
Associate Professor; PhD, University of Colorado Boulder

Minton, Timothy K. (https://experts.colorado.edu/display/fisid_167230/)
Professor; PhD, University of California Berkeley

Morton, Yu Jade (https://experts.colorado.edu/display/fisid_159076/)
Endowed/Named Professor; PhD, The Pennsylvania State University

Nabity, James A. (https://experts.colorado.edu/display/fisid_153102/)
Associate Professor; PhD, University of Colorado Boulder

Neogi, Sanghamitra (https://experts.colorado.edu/display/fisid_156773/)
Assistant Professor; PhD, Pennsylvania State University

Nerem, R. Steven (https://experts.colorado.edu/display/fisid_118478/)
Professor; PhD, University of Texas at Austin

Niederwieser, Tobias (https://experts.colorado.edu/display/fisid_164789/)
Assistant Research Professor; PhD, University of Colorado Boulder

Palo, Scott E. (https://experts.colorado.edu/display/fisid_109033/)
Professor; PhD, University of Colorado Boulder

Pao, Lucy Y. (https://experts.colorado.edu/display/fisid_107151/)
Professor; PhD, Stanford University

Park, Kwang-Chun
Professor Emeritus; PhD, Clarkson College

Peters, Sean (https://experts.colorado.edu/display/fisid_174034/)
Assistant Professor; PhD, Stanford University

Rafi, Melvin
Teaching Assistant Professor; PhD, Wichita State University

Rhode, Matthew (https://experts.colorado.edu/display/fisid_165079/)
Teaching Assistant Professor; BA, University of Colorado

Ruzzene, Massimo (https://experts.colorado.edu/display/fisid_165832/)
Professor; PhD, Politecnico Di Torino (Italy)

Schaub, Hanspeter (https://experts.colorado.edu/display/fisid_143818/)
Endowed/Named Professor, Chair; PhD, Texas A&M University

Scheeres, Daniel J. (https://experts.colorado.edu/display/fisid_145035/)
Distinguished Professor; PhD, University of Michigan Ann Arbor

Schwartz, Trudy L. (https://experts.colorado.edu/display/fisid_108607/)
Teaching Professor; MS, University of Colorado Boulder

Scott, Hank
Lecturer; MA, University of Queensland (Australia)

Shakiba, Maryam (https://experts.colorado.edu/display/fisid_172206/)
Assistant Professor; PhD, Texas AM University

Singer, Howard Joseph
Professor Adjunct; PhD, University of California, Los Angeles

Sternovsky, Zoltan (https://experts.colorado.edu/display/fisid_115211/)
Associate Professor; PhD, Charles University (Czech Republic)

Stodieck, Louis S. (https://experts.colorado.edu/display/fisid_105272/)
Research Professor; PhD, University of Colorado Boulder

Sunberg, Zachary (https://experts.colorado.edu/individual/fisid_165833/)
Assistant Professor; PhD, Stanford University

Thayer, Jeffrey P. (https://experts.colorado.edu/display/fisid_134469/)
Professor Emeritus, Research Professor; PhD, University of Michigan Ann Arbor

Thomas, Evan (https://experts.colorado.edu/display/fisid_163895/)
Associate Professor; PhD, University of Colorado Boulder

Voss, James S. (https://experts.colorado.edu/display/fisid_140891/)
Scholar in Residence; MS, University of Colorado Boulder

Williams, Christopher (https://experts.colorado.edu/display/fisid_105765/)
Research Professor; PhD, University of Colorado Boulder

Wingate, Kathryn (https://experts.colorado.edu/display/fisid_164029/)
Teaching Assistant Professor; PhD, University of Colorado Boulder

Courses

ASEN 5007 (3) Introduction to Finite Elements
Introduces finite element methods used for solving linear problems in structural and continuum mechanics. Covers modeling, mathematical formulation, and computer implementation.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite matrix algebra.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5010 (3) Spacecraft Attitude Dynamics and Control
Includes rigid body kinematics and spacecraft attitude descriptions, torque-free attitude dynamics, static attitude determination, motion and stability due to gravity gradient torque and spinning craft, passive and active methods of attitude control, nonlinear regulator and attitude tracking feedback controlaws.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3200, ASEN 3700, or equivalent and good knowledge of linear algebra, vector calculus, basics of ordinary differential equations.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 5012 (3) Mechanics of Aerospace Structures
Applies fundamental concepts of continuum mechanics, theory of elasticity and energy methods to the analysis of structures.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 5023
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors, and Aerospace graduate certificate students.
Recommended: Prerequisites APPM 2360 and ASEN 2001 or 2701 and ASEN 2003 or 2703 and ASEN 3112 or 3712 or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5014 (3) Linear Control Systems
Introduces the theory of linear systems, including vector spaces, linear equations, structure of linear operators, state space descriptions of dynamic systems, and state feedback control methods.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3200, ASEN 3700, or equivalent or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Systems and Control

ASEN 5016 (3) Space Life Sciences
Familiarizes students with factors affecting living organisms in the reduced-gravity environment of space flight. Covers basic life support requirements, human physiological adaptations, and cellular-level gravity dependent processes with emphasis on technical writing and research proposal preparation.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Bioastronautics and Microgravity Science

ASEN 5018 (3) Graduate Projects I
Exposes MS and PhD students to project management and systems engineering disciplines while working a complex aerospace engineering project as part of a project team. The project team may perform some or all of the following project activities during this first semester of the two-semester course sequence: requirements, definition, design and design review, build, test, and verification.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisite ASEN 4138 or ASEN 5148 or ASEN 5158 or instructor consent required.

ASEN 5022 (3) Dynamics of Aerospace Structures
Applies concepts covered in undergraduate dynamics, structures and mathematics to the dynamics of aerospace structural components, including methods of dynamic analysis, vibrational characteristics, vibration measurements and dynamic stability.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 5012 or ASEN 5227 or MATH 2130 or APPM 3310 or equivalent or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5034 (3) Stochastic Methods for Systems Engineering
Development of stochastic models used in aerospace and other systems engineering and optimization problems. Review of probability theory, stochastic models used in decision theory, random processes, queuing theory, information theory, reliability and quality control. Computer solutions required.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5044 (3) Statistical Estimation for Dynamical Systems
Introduces theory and methods of statistical estimation for general linear and nonlinear dynamical systems, with emphasis on aerospace engineering applications. Major topics include: review of applied probability and statistics; optimal parameter and dynamic state estimation; theory and design of Kalman filters for linear systems; extended/unscented Kalman filters and general Bayesian filters for non-linear systems.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Systems and Control

ASEN 5047 (3) Probability and Statistics for Aerospace Engineering Sciences
Considers probability concepts and theory for better design and control of aerospace engineering systems. Includes descriptive and inferential statistical methods for experimental analysis. Covers discrete and continuous random variable distributions, estimators, confidence intervals, regression, analysis of variance, hypothesis testing, nonparametric statistics, random processes and quality control, including software models of same.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Computational and Analytic Methods

ASEN 5050 (3) Space Flight Dynamics
Includes celestial mechanics, space navigation, and orbit determination; trajectory design and mission analysis trajectory requirements; and orbital transfer and rendezvous.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 5052
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3200 or ASEN 3700 or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 5051 (3) Fundamentals of Fluid Dynamics
Highlights physical properties of gases and liquids; kinematics of flow fields; and equations describing viscous, heat-conducting Newtonian fluids. Emphasizes exact solutions and rational approximations for low and high speed dissipative flows, surface and internal waves, acoustics, stability, and potential flows.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3111 or ASEN 3711 (minimum grade B) or an equivalent course.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerodynamics and Fluid Mechanics

ASEN 5052 (3) Analytical Astrodynamics
Introduction to astrodynamics with an emphasis on analytical approaches. The primary subjects covered are the general solution of the 2-body problem; orbital trajectories, transfers, targeting, and time of flight; orbit perturbations and averaging analysis; and the restricted 3-body problem. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 5050
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3200 or equivalent or instructor consent required.
Grading Basis: Letter Grade

ASEN 5053 (3) Space Propulsion
This course is designed to teach the theory, analysis and design of modern space propulsion systems. Lectures describe the thermodynamics of rocket propulsion and nozzle flow theory, followed by in¿depth study of cold gas thrusters, monopropellant and bipropellant liquid rockets, solid and hybrid rockets, electric propulsion, nuclear rockets, and solar sails. If time permits, other exotic propulsion technologies will be dealt with.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Thermodynamics and Propulsion

ASEN 5067 (3) Microavionics: Introduction to PIC Microcontrollers for Aerospace Systems
Provide students an introduction into embedded systems that teaches a basic understanding about the fundamental architecture of a microcontroller and how it operates and interfaces with both sensors and actuators applicable to aerospace engineering. Students will learn how to interface sensors to a PIC microcontroller, collect input, make decisions and take an action in real-time. To gain a full appreciation about how microcontrollers work, students develop their own software code using MPLAB X to program the development board hardware, which uses the Microchip PIC18F87K22 microcontroller as the foundation of the course. Students learn-by-doing through lab assignments and a semester final project. This includes programming in assembly language and then C, to collect data from external sources such as a serial terminal, temperature and rotary sensors, etc. and outputting results to a liquid crystal display (LCD), and sending commands to an actuator such as a servo.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 4067
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Grading Basis: Letter Grade

ASEN 5090 (3) Introduction to Global Navigation Satellite Systems
Global Navigation Satellite Systems (GNSS) are important tools for navigation, science, and engineering. Introduces GNSS hardware, signal structure, algorithms, error sources, and modeling techniques. Programming experience is required.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Global Positioning Systems

ASEN 5098 (3) System Engr and Design
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5111 (3) Introduction to Aeroelasticity
Introduces static and dynamic aeroelasticity of airfoils and wings. Covers the classical aeroelasticity theory and introduces computational methods for aeroelastic problems.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisites ASEN 3111 or MATH 2130 or APPM 3310 and MATH 3430 or equivalent or instructor consent required.
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5114 (3) Automatic Control Systems
Methods of analysis and design of feedback control for dynamic systems. Covers nyquist, bode and linear quadratic methods based on frequency domain and state space models. Laboratory experiments provide exposure to computation for simulation and real time control, and typical control system sensors and actuators.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 4114
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisites Undergraduate systems or control course or instructor consent (ASEN 3128 or ASEN 3200).
Additional Information: Departmental Category: Systems and Control

ASEN 5121 (3) Boundary Layers and Convection
This course presents an introduction to the principles of viscous fluid flow and methods for performing engineering calculations of quantities such as skin friction and heat transfer rates in boundary layers. The first portion of the course material will focus on basic principles of fluid mechanics. We will derive the Navier-Stokes equations and discuss some simple solutions to these equations. The second portion of the course will concentrate on the application of these principles to boundary layers. We will derive the boundary layer equations and discuss their approximate and almost exact solutions. Formerly offered as a special topics course.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3111 and/or ASEN 5051.
Grading Basis: Letter Grade

ASEN 5122 (3) Control of Aerospace Structures 1
Introduces the basic problems in dynamic modeling and active control of large spacecraft and satellites. Includes system descriptions, model reduction, controller design, and closed-loop stability analysis.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisite ASEN 3200 or equivalent or instructor consent required.
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5128 (3) Small Uncrewed Aircraft System Guidance, Navigation, and Control
Introduce students to advanced techniques for guidance, navigation, and control of the emerging class of small uncrewed aircraft systems (SUAS), which are informally defined as aircraft that weight less than 55 lbs.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 5131 (3) Introduction to Hypersonics
Introduces key elements of hypersonic vehicles, including trajectories, surface heating, propulsion, and thermal protection systems. Provides the necessary background on fluid dynamics and boundary layers, so students from a variety of disciplines are welcome. Also covers thermochemical nonequilibrium, surface pressure, and aerodynamic forces. Includes a mix of empirical techniques and computational analyses. Requires basic programming experience and exposure to partial differential equations.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 5137 (3) Experimental Design and Statistical Methods
Examines the applied issues of designing experiments and performing statistical analysis to reach justified scientific conclusions. Approaches are integrated to enable application to real-world research questions, with a focus on the unique challenges of human subject experiments.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: to Aerospace and Biomedical Engineering students.
Grading Basis: Letter Grade

ASEN 5148 (3) Spacecraft Design
Integrates the design elements and fundamental analyses necessary to complete the conceptual (Phase A) design of an unmanned spacecraft. Lecture and discussion explore mission design, propulsion, power, structure, thermal, attitude control, communication, command, and data handling and attitude control systems. The role of project management and systems engineering are examined. Resource estimating and lessons learned in satellite programs are reviewed.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5151 (3) Fundamentals of Gas Dynamics
Presents the fundamental topics of gas dynamics, focusing on compressible flows but providing connections to incompressible topics. Topics include analysis of quasi-one-dimensional flow, the partial differential equations governing inviscid compressible flows, linearized flow theory, supersonic flow around cones, and the method of characteristics applied to both steady two-dimensional supersonic flows, and unsteady one-dimensional flows.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3111 or equivalent.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerodynamics and Fluid Mechanics

ASEN 5158 (3) Space Habitat Design
Utilize systems engineering methods to design and analyze a spacecraft intended for human occupancy with functional knowledge of the technologies used to sustain life. Emphasis placed on deriving requirements from stated mission goals and objectives, developing integrated functional schematics into a conceptual design, and analyzing design options by mass/volume estimation, including launch vehicle selection.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5212 (3) Composite Structures and Materials
Develops the macromechanical and micromechanical theory of the elastic behavior and failure of composite laminates. Applies basic theory to a broad range of practical problems including the buckling and vibration of composite plates, columns, and shells.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5218 (3) Large Space Structures Design
Develops the necessary structural analysis skills for conducting conceptual and preliminary designs of large space structures with a practical emphasis on structures considered by NASA over the past 20 years. Applies analysis skills to a broad range of space missions requiring large space structures, emphasizing low cost and practical design.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 4218
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5222 (3) Materials Science for Composite Manufacturing
Studies common matrix materials and the modificationsand improvements of properties which can be achieved by adding second phase reinforcements. Properties will be significantly affected by the design approach and by requirements, and by the procedure of adding reinforcements. Investigates polymer, ceramic and metallic materials. Explores manufacturing, fabrication and processing techniques. Evaluates future developments.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 4222
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisites ASEN 3112 and ASEN 4012 or equivalent or instructor consent required.
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5226 (3) Medicine in Space and Surface Environments
Introduces concepts of space medicine and provides a focused analysis on exploration medical capabilities. This course provides a unique learning opportunity to understand the medical challenges of human spaceflight. This is done both in the classroom and in an immersive field simulation that allows students to engage in medical care in simulated planetary surface environments. As such, it also introduces students to important concepts in human spaceflight operations which are difficult to teach in the classroom.

ASEN 5235 (3) Introduction to Atmospheric Radiative Transfer and Remote Sensing
Examines fundamentals of radiative transfer and remote sensing with primary emphasis on the Earth's atmosphere; emission, absorption and scattering by molecules and particles; multiple scattering; polarization; radiometry and photometry; principles of inversion theory; extinction- and emission-based passive remote sensing; principles of active remote sensing; lidar and radar; additional applications such as the greenhouse effect and Earth's radiative energy budget.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Recommended: Prerequisite one year of calculus-based physics and math up through differential equations.
Additional Information: Departmental Category: Remote Sensing

ASEN 5245 (3) Radar and Remote Sensing
Examines active techniques of remote sensing, with emphasis on radar fundamentals, radar wave propagation, scattering processes, and radar measurement techniques and design. Examines specific radar systems and applications, such as synthetic aperture radar phased arrays for atmosphere, space, land, and sea applications.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Remote Sensing

ASEN 5251 (3) Molecular Thermodynamics and Kinetics
Provides an introduction to chemical kinetics and theories of molecular collisions and chemical reactions. Draws on quantum mechanics, statistical mechanics, and thermodynamics to help understand the magnitude of chemical reaction rates and how they vary with macroscopic parameters, such as temperature, and with microscopic parameters, such as molecular size, structure, and energy spacing.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite general chemistry, general physics, multivariable calculus.
Grading Basis: Letter Grade

ASEN 5254 (3) Algorithmic Motion Planning
Overview of the lessons learned by the robot motion planning community in the recent years. Examines approaches based on potential functions, graphs, sampling methods, task and motion planning, and basic approaches to planning under uncertainty. Provides a set of tools to tackle new problems and enables the pursuit of complex research questions such as planning for autonomous systems.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisites or corequisites: ASEN 5014 or equivalent, knowledge of how to plot 2-D/3-D functions, arrays and other data structures, standard constructs (loops, functions, etc), C++, Python or MATLAB, and knowledge of differential equations and linear algebra.
Grading Basis: Letter Grade

ASEN 5264 (3) Decision Making under Uncertainty
Covers algorithms for optimal sequential decision making in the presence of uncertainty. Mathematical formalisms include the Markov decision process (MDP), partially observable Markov decision process (POMDP), and Games. Solution techniques include exact dynamic programming, Monte Carlo tree search, deep reinforcement learning, and alpha vector value approximation for POMDPs. Assignments require programming in a high level language (Julia as of 2023). Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 5264
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite fluency in a high-level programming language, willingness to learn another language if required for homework assignments and basic understanding of probability.
Grading Basis: Letter Grade

ASEN 5307 (3) Engineering Data Analysis Methods
Gives students broad exposure to a variety of traditional and modern statistical methods for filtering and analyzing data. Topics include estimation methods, principal component analyses and spectral analyses. Introduces these methods and provides practical experience with their use. Students carry out problem assignments.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Computational and Analytic Methods

ASEN 5325 (3) Small Scale Processes in Geophysical Fluids
Provides an overview of mixing and wave processes in the oceans and the atmosphere. Topics include turbulent boundary layers in the lower atmosphere and the upper ocean, air-sea interactions, and surface and internal waves.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Atmospheric, Oceanic, and Space Sciences

ASEN 5335 (3) Aerospace Environment
Examines the components of the solar-terrestrial system and their interactions to provide an understanding of the re-entry and orbital environments within which aerospace vehicles operate. Includes the sun, solar wind, magnetospere, ionosphere, thermosphere, radiation belts, energetic particles, comparative environments (Mars, Venus, etc.), orbital debris, spacecraft charging, particle effects on systems, shielding, and satellite drag.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite Senior or graduate standing in engineering or related physical sciences.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Atmospheric, Oceanic, and Space Sciences

ASEN 5347 (3) Math Methods in Dynamics
Two-part graduate-level course on dynamics. Covers both flexible and rigid multibody analytical dynamics and finite element method for dynamics. Emphasizes formulations that naturally lead to easy computer implementation and stability, linearization, and modern rotational kinematics. Department consent required.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 5440 (3) Mission Design and Development for Space Sciences
Brings science and engineering students together to develop the multidisciplinary skills required to create a successful proposal to develop a NASA-funded small space mission. Goals: 1) develop the proposal science objectives based on scientific community priorities and NASA Announcement of Opportunity. 2) Understand how science requirements lead to the design of instrumentation. 3) Understand practical aspects of mission development.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5780
Requisites: Restricted to College of Engineering (ENGR) graduate students, Department of Astrophysical and Planetary Sciences graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and ASEN-P) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 5506 (1-2) Bioastronautics Seminar
Focuses on current topics related to space habitat systems design and research aimed at understanding the effects of spaceflight on living organisms ranging from humans down to microbes. Literature analysis and scientific presentations are expected. Emphasis is on biophysical mechanisms, comprehensive models, and related technology development.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Bioastronautics and Microgravity Science

ASEN 5519 (1-3) Special Topics
Reflects upon specialized aspects of aerospace engineering sciences. Course content is indicated in the online Class Search.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Recommended: Prerequisite varies.
Additional Information: Departmental Category: Specialized Courses

ASEN 5550 (3) Designing for Defense 1
Designing for Defense/Hacking for Defense is a national service program running at leading research universities across the country. Interdisciplinary teams¿chosen by competitive selection¿work on real-world national security challenges, in close contact with national security agencies. Teams employ the Lean Launchpad entrepreneurship methodology to develop engineering and business concepts to solve real-world challenges for special operations forces, the intelligence community, and other government agencies. Winning teams are eligible for real-world capital investment. The first semester of a two-course sequence. Students take this course, ASEN/CSCI/CYBR 5550, and ASEN/CSCI/CYBR 5580 contiguously as the sequence spans the academic year.
Equivalent - Duplicate Degree Credit Not Granted: CYBR 5550 and CSCI 5550
Grading Basis: Letter Grade

ASEN 5580 (3) Designing for Defense 2
This course allows teams to continue their D4D journey from semester 1 guiding
Requisites: Requires prerequisite course of ASEN 5550 or CSCI 5550 or CYBR 5550 (minimum grade B). Restricted to graduate students only.
Grading Basis: Letter Grade

ASEN 5849 (1-6) Independent Study
Study of special projects.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Specialized Courses

ASEN 5940 (1-3) Engineering Research Internship
Grants credit to foreign visiting graduate students for conducting research within the Aerospace Engineering Sciences department. Credits can be transferred to the student's home institution. CU-Boulder students may also receive credit for conducting research outside of the university, either overseas or in the US.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Specialized Courses

ASEN 6008 (3) Interplanetary Mission Design
Exploration of principles and methods related to the design and construction of trajectories for interplanetary mission design. Some topics covered include: two-and three-body motion, gravity assists, maneuver computation, navigation, numerical integration, and construction of orbits. The main focus is on simple ballistic mission designs, such as Galileo or Cassini, however, libration point trajectories will also be covered.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 5050 or ASEN 5052.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6009 (1-2) Special Topics Seminar
Presents research and developments in each department's focus areas.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Specialized Courses

ASEN 6010 (3) Advanced Spacecraft Dynamics and Control
Studies the dynamic modeling and control of spacecraft containing multiple momentum exchange devices, and/or flexible spacecraft components. Will develop nonlinear feedback control algorithms, explore singularity avoidance strategies. The second half of the course derives analytical methods (D'Alembert's equations, Lagrange's equations, Boltzmann Hamel equations) to model a hybrid rigid/flexible spacecraft system.
Requisites: Requires prerequisite course of ASEN 5010 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6011 (3) Experimental Fluid Mechanics
This course presents an intermediate level introduction into the theory and practice of performing experimental measurements in fluid mechanics. The fundamental principles and definitions associated with instrumentation, measurement procedures, data analysis, and uncertainty quantification will be discussed. A specific focus will be placed on the application of a variety of measurement techniques in low-speed aerodynamic environments. A selection of measurement techniques will be extensively studied and applied including: classical pressure and temperature measurements, thermal (hot-wire) anemometry, laser doppler anemometry, particle image velocimetry, surface and field flow visualization techniques, schlieren and shadowgraph photography techniques. Undergraduates may enroll with instructor permission. Previously offered as a special topics course.
Requisites: Requires prerequisite or corequisite course of ASEN 5051 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 6013 (3) High Speed Propulsion
Covers air-breathing and rocket propulsion cycles, their relative performance trade-offs, and how they fit within the context of a vehicle system. Specific emphasis will be placed on fundamental cycle analyses, component level design, and propulsion/airframe integration for rockets, turbojets, ramjets, scramjets, combined cycles, and other advanced propulsion concepts.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisite ASEN 4013 or equivalent or instructor consent required.
Additional Information: Departmental Category: Thermodynamics and Propulsion

ASEN 6014 (3) Spacecraft Formation Flying
Studies the dynamic modeling and control of spacecraft formations orbiting about a planet. Investigate linear and nonlinear relative motion descriptions, rectilinear and curvilinear coordinates, orbit element difference based descriptions, J2-invariant relative orbits, as well as Lyapunov-based relative motion control strategies.
Requisites: Requires prerequisite course of ASEN 5050 or ASEN 5052 (minimum grade B-). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Systems and Control

ASEN 6015 (3) Space Vehicle Guidance and Control
The course gives a comprehensive view of guidance systems used in space vehicles, and methods for analyzing the performance of these systems. The types of guidance systems that will be covered are launch vehicle ascent, intercept/rendezvous, interplanetary, orbit station-keeping, atmospheric re-entry, lander, and low-thrust. The mathematical foundation of these systems will be derived and discussed. Real world applications will be presented by reviewing selections from published literature. Course work will emphasize the analysis of the guidance system performance to achieve stated goals. Previously offered as a special topics course.
Requisites: Requires prerequisite courses of ASEN 5014 and ASEN 5050 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.

ASEN 6020 (3) Optimal Trajectories
Introduces the theory and practice of trajectory optimization. The general theory behind optimization and optimal control will be introduced with an emphasis on the properties of optimal trajectories. The main application will be to space trajectories, but other applications will also be considered.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisites ASEN 5050 and ASEN 5014 or instructor consent required.
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6024 (3) Nonlinear Control Systems
Introduces the analysis and control design methods for nonlinear systems, including Lyapunov, Describing Function, and Feedback Linearization methods.
Requisites: Requires prerequisite course of ASEN 5014 (minimum grade C). Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Systems and Control

ASEN 6028 (3) Graduate Projects II
Exposes MS and PhD students to leadership positions in project management and systems engineering while working a complex aerospace engineering project as part of a project team. The project team may perform some or all of the following project activities during this second semester of the two-semester course sequence: requirements definition, design and design review, build, test, and verification.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Recommended: Prerequisite ASEN 4138 or ASEN 5148 or ASEN 5018 or ASEN 5158 or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 6037 (3) Turbulent Flows
Studies turbulent closure methods and computational procedures used to solve practical turbulent flows. Emphasizes multi-equation models used with time-averaged equations to calculate free-turbulent shear-flows and turbulent boundary layers. Employs spectral methods in direct and large-eddy simulation of turbulence. Formerly ASEN 5037.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Recommended: Prerequisite ASEN 5051 or equivalent or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerodynamics and Fluid Mechanics

ASEN 6044 (3) Advanced State Estimation
Introduces principles and techniques for designing, implementing, and analyzing probabilistic state estimators for dynamical systems that require going beyond traditional least-squares and Kalman filtering approaches. Emphasis on development of practical discrete-time Bayesian state space filtering algorithms for systems characterized by partial observability and non-Gaussian uncertainties, which arise in many applications governed by complex non-linear stochastic dynamics and measurement processes.
Requisites: Requires prerequisite ASEN 5044 (min grade B+). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 6050 (3) Space Instrumentation
Provides an overview of the relevant space environment and process, the types of instruments flown on recent mission and the science background of the measurement principles.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 6050 and GEOL 6050
Requisites: Requires prerequisite course of ASEN 5335 (minimum grade D-).
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 6055 (3) Data Assimilation & Inverse Methods for Earth & Geospace Observations
Covers a selection of topics in probability theory, spatial statistics, estimation theory, numeric optimization, and geophysical nonlinear dynamics that form the foundation of commonly used data assimilation and inverse methods in the Earth and Space Sciences. Hands-on computational homework and projects provide opportunities to apply classroom curricula to realistic examples in the context of data assimilation.
Requisites: Requires prerequisite course of ASEN 5044 (minimum grade B-). Restricted to graduate students.
Grading Basis: Letter Grade

ASEN 6060 (3) Advanced Astrodynamics
Covers Lagrangian and Hamiltonian formalisms for astrodynamics problems, the computation and characterization of space trajectories in highly dynamic environments, computation of periodic orbits, stability analysis of orbital motion, and development of analytical theories for dynamics.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 5050 or equivalent or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6061 (3) Molecular Gas Dynamics and DSMC
Describes the composition and flow of gases on a microscopic level to examine the behavior of the molecules that make up a macroscopic flow system. Thermodynamic properties, transport phenomena, and the governing Boltzmann Equation are derived from molecular collision dynamics and the kinetic theory. The Direct Simulation Monte Carlo method is introduced with applications.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Additional Information: Departmental Category: Aerodynamics and Fluid Mechanics

ASEN 6070 (3) Satellite Geodesy
Focuses on the measurement of the Earth's gravitational field, rotational characteristics, and shape using Earth and space-based tracking of artificial satellites. Particular emphasis on satellite altimetry and satellite gravity measurements.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 3200 or equivalent or instructor consent required.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6080 (3) Statistical Orbit Determination
Course on orbit and advanced estimation techniques. Emphasizes orthogonal transformation techniques such as Givens and Householder, square root filtering and smoothing and considers covariance analysis. Also nonlinear filters and dynamic model compensation techniques. Requires term project that involves the application of many of the techniques required for precise orbit determination.
Requisites: Requires prerequisite course of ASEN 5044 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN) majors and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Astrodynamics and Orbital Mechanics

ASEN 6084 (3) Optical Multi-Target Tracking
This course focuses on exploiting sensor information to detect, track, and characterize unresolved objects using optical sensors. This course will cover phenomenological modeling, error statistics, image processing, detection methods, and several multi-object tracking frameworks. Assignments and projects will incorporate both simulated and empirical data generation / collection and reduction.
Requisites: Requires prerequisite course ASEN 5044 (minimum grade D-) .Restricted to College of Engineering (ENGR) graduate students.

ASEN 6090 (3) Advanced Global Navigation Satellite Systems: Software and Applications
Focuses on high-precision applications of Global Navigation Satellite Systems (GNSS) and the software tools that are needed to achieve these precisions. Topics include precise orbital determination, reference frames, atmospheric delays, relativity, clock models, ambiguity resolution, and scientific applications.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisite ASEN 5090 or instructor consent required.
Additional Information: Departmental Category: Global Positioning Systems

ASEN 6091 (3) Global Navigation Satellite System (GNSS) Receiver Architecture
Investigates the overall architecture of satellite navigation receivers: including both the analog radio frequency conditioning (antenna to the analog-to-digital converter) and the various signal processing algorithms. Such treatment of the operation of the receiver will provide insight into the trade-offs that go into GNSS as well as the more broad generic spread spectrum receiver design.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 5090.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Global Positioning Systems

ASEN 6092 (3) GNSS for Remote Sensing of the Atmosphere, Ionosphere, and Earth Surface
Covers technologies that rely on GNSS signals for remote sensing applications. GNSS receiver signal processing techniques and GNSS signal propagation effects due to interactions with the ionosphere, neutral atmosphere, and Earth surface are addressed. Students will learn techniques to process GNSS measurements and to infer ionospheric, atmospheric, and Earth surface properties from real GNSS measurements collected by ground-based receivers and LEO satellites.
Requisites: Requires prerequisite course of ASEN 5090 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 6107 (3) Nonlinear Finite Element Methods
Continuation of ASEN 5007. Covers the formulation and numerical solution of nonlinear static structural problems by finite element methods. Emphasizes the treatment of geometric nonlinearities and structural stability.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: Prerequisite ASEN 5007 or equivalent or instructor consent required.
Additional Information: Departmental Category: Specialized Courses

ASEN 6114 (3) System Identification for Control
Explores methods for identification of models for physical processes which will be part of a feedback control system. Focuses on the interplay between robustness of control laws and the performance of identification methods. Covers time-domain and frequency-domain identification methods, using experimental simulations of control systems of interest to the class.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisite ASEN 5014 or ASEN 5114.
Grading Basis: Letter Grade

ASEN 6116 (3) Spacecraft Life Support Systems
Study the environmental control and the life support systems and technologies that keep people alive and healthy in spacecraft and habitats. Students will learn about thermal control systems, air revitalization processes, water reclamation and treatment, waste handling and the reuse of materials, and food and nutrition. Expect to develop analytical models from first principles and perform hands-on laboratory experiments. Formerly ASEN 5116.
Requisites: Requires prerequisite course of ASEN 5158 (minimum grade D-). Requires corequisite course of ASEN 5016. Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Bioastronautics and Microgravity Science

ASEN 6216 (3) Human Operation of Aerospace Vehicles
Examines the role, capabilities, and limitations of human operators in aerospace vehicles. Topics include theoretical models of human information processing and decision-making, physiological limitations of the human (particularly spatial orientation illusions), the design of display and control interfaces, and the evaluation of those interfaces for human interaction with complex aerospace systems.
Requisites: Requires prerequisite or corequisite course of ASEN 5158 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students.
Recommended: for aerospace and biomedical engineering students.
Grading Basis: Letter Grade

ASEN 6265 (3) Fundamentals of Spectroscopy for Optical Remote Sensing
Provides a comprehensive overview of the fundamentals of quantum physics, atomic spectroscopy, molecular spectroscopy and laser spectroscopy. Exposes students to the spectroscopy applications in modern optical and laser remote sensing. Assists students to develop the fundamental knowledge and skills for independent learning.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade

ASEN 6316 (3) Extravehicular Activity
Expose students to all aspects of extravehicular activity (EVA) to enable them to design systems to facilitate EVA for future human exploration. This course will draw upon the academic elements of design, engineering, technology development, physiology, operations, human-machine interaction, and geology to provide an interdisciplinary look at this topic.
Requisites: Requires prerequisite course of ASEN 5158 or ASEN 5016 (minimum grade D-). Restricted to College of Engineering (ENGR) graduate students and Aerospace graduate certificate students.
Recommended: aerospace or biomedical engineering students with a focus in bioastronautics.
Grading Basis: Letter Grade

ASEN 6331 (3) Computational Fluid Dynamics
Focuses on computational approaches to solve the Navier-Stokes equations. Assumes a basic knowledge of the solution of partial differential equations with numerical methods with focus finite element/volume methods (FEM/FVM but primarily FEM). These issues include: the discrete formulation, non-linear equation iterator, linear equation formation, boundary condition prescription and linear equation solution.
Requisites: Requires prerequisite or corequisite courses of ASEN 5007 and ASEN 5051 (minimum grade C). Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Recommended: instructor permission required if pre/co requisite of ASEN 5007 and ASEN 5051 haven¿t been met.

ASEN 6337 (3) Remote Sensing Data Analysis
Covers some of the most commonly used machine learning techniques in remote sensing data analysis, specifically for clustering, classification, feature extraction and dimensionality reduction, and inverse methods used to retrieve geophysical information from remote sensing data. Hands-on computational homework and group and individual projects provide opportunities to apply classroom curricula to real remote sensing data.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN) majors only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Remote Sensing

ASEN 6365 (3) Lidar Remote Sensing
Provides a comprehensive, yet easily understandable, up-to-date understanding of lidar principles, technologies and applications. Contains approaches for quantitative lidar simulation, lidar sensitivity and error analysis, lidar data retrieval, lidar system design and performance analysis. Gives students opportunities to see and operate real state-of-the-art lidar systems and make connections to lidar experts in the nation and world.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Aerospace Design and System Engineering

ASEN 6412 (3) Uncertainty Quantification
This advanced topics course provides an exploration of techniques for representation and propagation of uncertainty in PDE/ODE-based systems.
Requisites: Restricted to College of Engineering (ENGR) graduate students, Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors, and Aerospace graduate certificate students.
Recommended: Prerequisites APPM 5570 and ECEN 5612 (all minimum grade B) or equivalent courses with instructor consent.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Structures, Materials, and Structural Dynamics

ASEN 6519 (1-3) Special Topics
Reflects upon specialized aspects of aerospace engineering sciences. Course content is indicated in the online Schedule Planner.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to College of Engineering (ENGR) graduate students or Aerospace Engineering Concurrent Degree (C-ASEN and C-ASENP) majors only.
Recommended: Prerequisite varies.
Additional Information: Departmental Category: Specialized Courses

ASEN 6800 (3) Master of Engr Project
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Specialized Courses

ASEN 6849 (1-6) Independent Study
Studies special projects agreed upon by student and instructor.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Specialized Courses

ASEN 6949 (1) Master's Candidate for Degree
Registration intended for students preparing for a thesis defense, final examination, culminating activity, or completion of degree.
Additional Information: Departmental Category: Specialized Courses

ASEN 6950 (1-6) Master's Thesis
Additional Information: Departmental Category: Specialized Courses

ASEN 8990 (1-10) Doctoral Dissertation
Additional Information: Departmental Category: Specialized Courses