Department of Aerospace Engineering

Aerospace Engineering

The aerospace engineer is concerned with the design, production, operation, and support of aircraft and spacecraft. Aerospace engineers conduct research to advance air flight and space exploration, by solving problems, developing products, and improving processes for the aerospace industry. Aerospace engineers typically work for aircraft and space vehicle industries, national research laboratories, commercial airlines, and federal government agencies. The curriculum includes traditional courses in aerodynamics, flight dynamics and control, propulsion, structures, manufacturing, instrumentation, and spacecraft systems.

VISION

KU Aerospace Engineering (KUAE) is a world-class community of choice for outstanding students, educators, and researchers shaping the next generation of aerospace systems.

MISSION STATEMENT

KUAE fosters a world-class community of choice for students, educators, researchers, and industry partners by strategically aligning our teaching, research, and service missions to prepare students for successful professional careers by providing them with foundational knowledge in and experience with aerospace engineering disciplines and interdisciplinary systems integration while advancing the state-of-the-art

- We are an international leader in undergraduate, graduate, and continuing aerospace education, balancing theory and practice to best prepare our graduates for professional practice and for higher education
- We provide world-class graduate and undergraduate research experiences focused on designing, simulating, building, testing, and flying aerospace vehicles and systems, including practical experience in applying aerospace fundamentals to interdisciplinary research and advancing knowledge.
- We invest in research infrastructure and select and develop outstanding and diverse students, faculty, and staff to maintain an intellectually stimulating and collegial atmosphere in which to conduct globally significant basic and applied research
- We support the aerospace profession by educating the public through outreach, educating working professionals through the KU Aerospace Short Course program and advising policy-makers in government, industry, and professional organizations.
- We partner with the aerospace industry through directed research, internships, and professional mentoring to ensure that our graduates are recognized and hired as those best prepared for professional success.

KUAE STRATEGIC GOALS

To support our teaching mission:

- Attract, develop, and retain the highest quality students representing broad demographics
- Provide immersive, experiential learning opportunities integrated across the curriculum
- Expand the number and frequency of higher-level graduate course offerings
- Attract, advance, and retain an outstanding and diverse technical staff to support cutting-edge, holistic, education and research
- Achieve and maintain a state-of-the-art distance education capability to expand educational outreach to remote learners and increase access to remote expertise for local learners
- Develop and modernize facilities appropriate to providing intellectually stimulating curricular experiences

To increase the quality and volume of funded research:

- Attract, advance, and retain a diverse and continuously growing number of world-class faculty and research staff
- Attract and develop the highest quality graduate students representing broad demographics, with a particular emphasis on increasing the number of doctoral students
- Develop high-quality, state-of-the-art research facilities appropriate to enabling globally significant basic and applied research
- Attract, advance, and retain an outstanding and diverse technical staff to support cutting-edge, holistic, education and research
- Strategically target and transition technologies of national importance to enhance interdisciplinary, collaborative research
- Expand partnerships with industry leaders in directed research

To provide service:

- Be leaders in preparing our graduates for successful professional careers
- Be leaders in national and international technical and academic societies and editorial boards
- Expand the internationally renowned KU Aerospace Short Course and distance learning programs

Undergraduate Programs

The curriculum includes traditional courses in aerodynamics, flight dynamics and control, propulsion, structures, manufacturing, instrumentation, and spacecraft systems. Capstone design courses are offered in aircraft, propulsion, and spacecraft design.

Graduate Programs

The Department of Aerospace Engineering offers traditional Master of Science (MSAE) and Doctor of Philosophy (PhDAE) programs which emphasize original analytical and experimental research. In addition, two unique programs are offered: the Master of Engineering (MEAE) and the Doctor of Engineering (DEAE), which emphasize system design and management. Each of these programs provide excellent preparation for employment in industry or in private and government laboratories. The doctoral programs also prepare for an academic career in teaching and research. The Master of Science and Master of Engineering programs have options for an in-person or online degree.

Graduate course work is available in the following areas of aerospace engineering:

- aerodynamics
- computational fluid dynamics

- propulsion
- structures
- flight dynamics and control
- aircraft design
- spacecraft design
- orbital mechanics

Graduate courses are taught by faculty with a strong background in graduate education and in industry and government laboratory experience. All faculty are currently active in funded or unfunded research in their areas of expertise. Department research programs are typically funded by: NASA, DOD, DOE, NSF, FAA, and the Aerospace industry.

Courses

AE 211. Computing for Engineers. 3 Credits.
Introduction to computing concepts. Introduction to the MATLAB computing language using a suite of simulations in science and engineering in a progression which adds new MATLAB constructs - as well as logical and mathematical constructs - with each simulation. Simulations include numerical integration, coordinate transformations and primitive reinforcement learning constructs. Prerequisite: MATH 125 or MATH 145 with a grade of C- or higher.

AE 245. Introduction to Aerospace Engineering. 3 Credits.
Basic systems of an aerospace vehicle, meteorology, vehicle performance, navigation and safety. Specific examples emphasize general aviation. Open to students with less than 60 hours completed. Other students need permission of instructor. Prerequisite: Corequisite: MATH 125 or MATH 145.

AE 290. Aerospace Colloquium. 0.25 Credits.
This is a required course for all aerospace engineering majors. Topics of importance such as social responsibility, ethics, communication, and new technical developments are discussed by aerospace industry representatives and representatives of F.A.A., D.O.T., D.O.D., N.A.S.A., related sciences, and engineering disciplines. A forum for student activities at all levels. Open enrollment.

AE 345. Fluid Mechanics. 3 Credits.
Study of fundamental aspects of fluid motions and basic principles of gas dynamics with application to the design and analysis of aircraft. Prerequisite: C- or higher in MATH 126 or MATH 146. Corequisite: AE 245, CE 260, and MATH 220; or permission of instructor.

AE 360. Introduction to Astronautics. 3 Credits.
Introduction to astronautical engineering. The history of astronautics, including rocketry and space flight. Fundamentals of astronautics, including space environment, astrodynamics and the analysis and design of spacecraft systems. Design, construction and launch of a prototype earth-satellite using a high-altitude balloon. Prerequisite: MATH 126 or MATH 146, and CE 260 or equivalent with a grade of C- or higher. Corequisite: AE 211, ME 208, or EECS 138.

AE 400. Special Topics: _____. 1-3 Credits.
A course in a topic related to undergraduate studies in Aerospace Engineering. Varies by topic or with consent of instructor.

AE 421. Aerospace Computer Graphics. 3 Credits.
Development of skills in depicting aerospace vehicles and their components and subsystems for the purpose of illustration, design, and analysis using traditional and modern (Computer Aided Design) drafting tools. Prerequisite: C- or higher in MATH 126 or MATH 146, and CE 201, or CE 260, or CE 301. Corequisite: CE 310 or equivalent, or permission of instructor.

AE 430. Aerospace Instrumentation Laboratory. 3 Credits.
Review and hands-on laboratory experiments with basic electronic elements (resistors, capacitors, conductors, transistors, linear circuits, logic devices, and integrated circuits). Overview and hands-on laboratory experiments using various experimental techniques available to the aerospace engineers (pressure probes, thermocouples, strain gauges, hot-wire anemometer, laser Doppler velocimeter, and flow visualization techniques). Prerequisite: AE 445 with a grade of C- or higher.

AE 445. Aircraft Aerodynamics and Performance. 3 Credits.
Study of airfoil and wing aerodynamics, component drag, static and special performance, and maneuvers of aircraft. Open enrollment. Prerequisite: AE 345 and CE 260 or CE 201 and CE 250, all with grades of C- or higher.

AE 490. Aerospace Industrial Internship. 1 Credits.
Engineering internship in an approved company. Internship hours do not satisfy any course requirements for the bachelors degree in Aerospace Engineering but will appear on the official transcript. Credit assigned after review of report on internship experience. Graded on a satisfactory/fail basis. Prerequisite: Completion of junior year.

AE 500. Undergraduate Extended Topics: _____. 1 Credits.
An extension of specific AE 500-level courses in order to meet transitional degree requirements. This course does not meet the AE Technical Elective requirements. Prerequisite: Varies by topic or with consent of instructor.

AE 506. Aerospace Structures I, Honors. 3 Credits.
In depth analysis and design of aerospace structures from the standpoint of preliminary design. Deflection and stress analysis of structural components, including thin-walled beams and built-up (semimonocoque) structures. Material failure of highly stressed components, including connections. Buckling of thin-walled beams and semimonocoque structures. Durability and damage tolerance strategies for aerospace structures to avoid corrosion, fatigue, and fracture. Prerequisite: CE 310 or CE 312 with a grade of C- or higher and permission of instructor. Must have minimum 3.25 KU GPA.

AE 507. Aerospace Structures I. 3 Credits.
Analysis and design of aerospace structures from the standpoint of preliminary design. Deflection and stress analysis of structural components, including thin-walled beams and built-up (semimonocoque) structures. Material failure of highly stressed components, including connections. Buckling of thin-walled beams and semimonocoque structures. Durability and damage tolerance strategies for aerospace structures to avoid corrosion, fatigue, and fracture. Prerequisite: CE 310 or CE 312 with a grade of C- or higher.

AE 508. Aerospace Structures II. 3 Credits.
Stress and deflection analysis of aerospace structures using the finite element method. Introduction to work-energy principles, including Castigliano's Theorems, for the analysis of statically indeterminate structures. Rod, beam, shaft, membrane, and plate finite elements. Prerequisite: AE 506 or AE 507, and MATH 290 or MATH 291 with a grade of C- or higher.

AE 509. Honors Aerospace Structures II. 3 Credits.
Indeterminate structures, principle of virtual work, Castigliano's theorems, displacement method of finite element analysis; rod, beam, shaft, and membrane elements; analysis of aerospace structures with the finite element method. Prerequisite: AE 506 or AE 507, and MATH 290 or MATH 291 with a grade of C- or higher, and minimum 3.25 KU GPA.

AE 510. Aerospace Materials and Processes. 3 Credits.
Properties and applications of aircraft materials, forming methods, and manufacturing processes. Ethics and social responsibility for engineers. Oral technical presentations. Prerequisite: AE 507 or AE 506, and CHEM 150 or CHEM 130 and CHEM 149.

AE 520. Space Systems Design I. 4 Credits.
Preliminary design techniques for a space system. Systems engineering; orbital mechanics; spacecraft subsystems including propulsion, attitude control, power, thermal command and data, communications, and structures; and ethics and social responsibility for engineers. Written technical reports. Prerequisite: AE 360 or EPHX 521, AE 421, AE 508 or AE 509, ME 212 with a C- or higher, and CHEM 150 or CHEM 130 and CHEM 149, or permission of instructor.

AE 521. Aerospace Systems Design I. 4 Credits.
Preliminary design techniques for an aerospace system. Aerodynamic design, drag prediction, stability and control criteria, civil and military specifications. Weight and balance, Configuration integration, design and safety, design and ethics, and social responsibility for engineers. Written technical reports. Prerequisite: AE 421, AE 508 or AE 509, AE 551 or AE 552, AE 572 or AE 573, and CHEM 150 or CHEM 130 and CHEM 149 or permission of instructor.

AE 522. Aerospace Systems Design II. 3 Credits.
Preliminary design project of a complete aircraft system. Technical written reports and oral presentations. Prerequisite: AE 521 or AE 520 and permission of instructor. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 523. Space Systems Design II. 3 Credits.
Preliminary design project of a complete space system. Technical written reports and oral presentations. Prerequisite: AE 520 or AE 521 and permission of instructor. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 545. Fundamentals of Aerodynamics. 3 Credits.
Basic gas dynamic equations, potential flow for airfoils and bodies, thin airfoil theory, finite wing, subsonic similarity rules, one and two dimensional supersonic flow, boundary layers, heat transfer, and laboratory experiments. Prerequisite: A grade of C- or higher in AE 445, ME 212, MATH 127 or MATH 147, and MATH 220 or MATH 221.

AE 546. Aerodynamics, Honors. 3 Credits.
Basic gas dynamic equations, potential flow for airfoils and bodies, thin airfoil theory, finite wing, subsonic similarity rules, one and two dimensional supersonic flow, boundary layers and viscous flow, heat transfer, and laboratory experiments. A special project in aerodynamics for AE 546 students. Prerequisite: AE 445, ME 212, MATH 220 or MATH 221, and MATH 290 or MATH 291, all with C- or higher and minimum 3.25 KU GPA.

AE 550. Dynamics of Flight I. 3 Credits.
Introduction to Tensors Algebra. Frames and coordinates in dynamics systems. General equations of motion of rigid airplanes and reduction to steady state flight situations. Steady state forces and moments. Stability derivatives. Static stability, control and trim. Trim envelope. Relationships with handling quality requirements. Engine-out flight. Effects of the control system. Implications to airplane design. Prerequisite: Grade of C- or higher in AE 211, and MATH 127 or MATH 147, and MATH 220 or MATH 221. Corequisite: AE 545 or AE 546 and MATH 290 or MATH 291, or permission of instructor.

AE 551. Dynamics of Flight II. 3 Credits.
General equations of motion of rigid airplanes and reduction to perturbed state flight situations. Mathematical modeling of airplane and control system analysis in state space. Dynamic stability, phugoid, short period, dutch roll, roll, spiral, and other important modes. Transfer functions and their application. Relationships with handling quality requirements. Fundamentals of classical control theory and applications to automatic flight controls. Implications to airplane design. Prerequisite: AE 545 or AE 546, AE 550, and a grade of C- or higher in MATH 290 or MATH 291.

AE 552. Honors Dynamics of Flight II. 3 Credits.
General equations of motion of rigid airplanes and reduction to perturbed state flight situations. Perturbed state forces and moments, stability derivatives, dynamic stability, phugoid, short period, dutch roll, roll, spiral, and other important modes. Transfer functions and their application. Relationships with handling quality requirements. Fundamentals of classical control theory and applications to automatic flight controls. Implications to airplane design. Prerequisite: AE 545 or AE 546, AE 550, and a grade of C- or higher in MATH 290 or MATH 291, and minimum 3.25 KU GPA.

AE 571. Fundamentals of Airplane Reciprocating Propulsion Systems. 3 Credits.
Study of the basic principles of operation and systems of internal and external combustion engines with emphasis on airplane reciprocating engines. Cycle analysis, propeller theory, propeller selection and performance analysis. Prerequisite: AE 445 and ME 212 with grades of C- or higher.

AE 572. Fundamentals of Jet Propulsion. 3 Credits.
Lecture and laboratory, study of basic principles of propulsion systems with emphasis on jets and fan systems. Study of inlets, compressors, burners, fuels, turbines, jets, methods of analysis, testing, performance; environmental considerations. Prerequisite: AE 545 or AE 546, AE 571, and CHEM 150 or CHEM 130 and CHEM 149.

AE 573. Honors Propulsion. 3 Credits.
Lecture and laboratory, study of basic principles of propulsion systems with emphasis on jets and fan systems. Study of inlets, compressors, burners, fuels, turbines, jets, methods of analysis, testing, performance; environmental considerations. Prerequisite: AE 545 or AE 546, AE 571, and CHEM 150 or CHEM 130 and CHEM 149, and minimum 3.25 KU GPA.

AE 590. Aerospace Senior Seminar. 1 Credits.
Presentation and discussion of technical and professional paper reports. Methods for improving oral communication. Discussion of topics such as ethics, registration, interviewing, professional societies, personal planning. Prerequisite: Senior standing.

AE 592. Special Projects in Aerospace Engineering for Undergraduate Students. 0.25-5 Credits.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor.

AE 593. Honors Research. 1-5 Credits.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor.

AE 600. Special Topics: _____. 1-3 Credits.
A graduate course or colloquium in a topic related to graduate studies in Aerospace Engineering. This course does not count towards hours needed for completion of degree program. Prerequisite: Varies by topic or with consent of instructor.

AE 621. Advanced Aircraft Design Techniques I. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through design work. This design work will involve detailed design of efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design and aerodynamic design.

Prerequisite: AE 507, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently.

AE 690. Professional Development for Graduate Studies. 0.25 Credits.
Professional development for graduate students. Responsible conduct of research. Presentation and discussion of graduate student research. Oral communication to a range of audiences, including short presentations by students on a range of topics. One semester of enrollment required for all MS and ME candidates, and two semesters of enrollment required for all PhD and DE aspirants and candidates. Graded on a satisfactory/unsatisfactory basis.

AE 700. Special Topics: _____. 1-5 Credits.
Courses on special items of current interest in aerospace engineering, given as need arises. May be repeated for additional credit. Prerequisite: Approval of instructor.

AE 704. Dynamics and Vibrations. 3 Credits.
Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degree of freedom in vibrational systems. (Same as CE 704.) Prerequisite: AE 508 or AE 509 or CE 461 or ME 628.

AE 705. Structural Vibrations and Modal Testing. 4 Credits.
Classical theory of structural vibrations. Single and multiple degree of freedom free and forced vibration. Theory of modal summation. Measurement techniques for dynamic data. Methods of identifying modal parameters from measurement data. Numerous laboratory and computational projects. Prerequisite: AE 508 or AE 509.

AE 709. Structural Composites. 3 Credits.
Fiber materials, tapes, cloths, resin systems; general aeolotropic theory, elastic constants, matrix formulation; computer analysis, strength, theory of failure; introduction to design with composites, preliminary design, optimization, processing variables, product design. Prerequisite: AE 508 or AE 509 or CE 761, and CHEM 150 or CHEM 130 and CHEM 149. Corequisite: AE 510 or ME 306 or CE 710.

AE 712. Techniques of Engineering Evaluation. 3 Credits.
The formulation of problems arising in aerodynamics, heat transfer, stress analysis, thermodynamics, and vibrations. The expression of these problems in a form amenable to quantitative evaluation by dimensional reasoning, analog techniques, relaxation methods, and classical analysis.

AE 721. Aircraft Design Laboratory I. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design. Prerequisite: AE 507 or AE 506, AE 545 or AE 546, AE 551 or AE 552, AE 571. Co-requisite: AE 521 or AE 520 and permission of instructor, and ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 722. Aircraft Design Laboratory II. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design. Prerequisite: AE 507 or AE 506, AE 521, AE 545 or AE 546, AE 551 or AE 552, and AE 571. AE 522 may be taken concurrently. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 725. Numerical Optimization and Structural Design. 3 Credits.
Classical theories of unconstrained and constrained optimization. Numerical techniques for unconstrained optimization, including the steepest descent, conjugate gradient and "Newton's" methods. Numerical techniques for constrained optimization, including sequential approximate problem techniques as well as the method of feasible directions. Computer aided solutions to practical design problems in aerospace engineering. Final design project. Prerequisite: C- or higher in MATH 220 or MATH 221 and MATH 290 or MATH 291.

AE 727. Aircraft Antenna Systems. 3 Credits.
Aircraft antenna integration and design process. Overview of common aircraft communication, navigation, and sensing systems. CAD tools and analysis and measurement techniques for designing and assessing systems. Low-observable vehicle design concepts. Prerequisite: PHSX 212 and MATH 127 or MATH 147 with a grade of C- or higher, EECS 316, AE 421 or other CAD experience, and CE 310 or equivalent recommended.

AE 730. Advanced Experimental Fluid Dynamics. 3 Credits.
Theory, methods and data analysis of various modern flow measurement techniques including: hotwire cluster, laser-Doppler velocimetry, particle image velocimetry, holography, pressure detection, temperature probing, vorticity measurements, Lagrange particle tracking. Specific experimental technique covers optical measurements in turbulent flow, microfluidic experiments, and spray and multiphase flow measurement. Prerequisite: AE 430, AE 545 or AE 546 or consent of instructor.

AE 732. Introduction to Flight Test Engineering. 3 Credits.
Course presents flight test principles, instrumentation, planning, and operation of aerospace vehicle flight testing. Course is structured with lectures, laboratories, and flight experiments. Student teams plan and execute a series of flight test experiments including: familiarization with flight test measurements, static system calibration, rate-of-climb performance, and determination of vehicle flight dynamics. Prerequisite: AE 445 and AE 550 or consent of instructor.

AE 743. Compressible Aerodynamics. 3 Credits.
Compressible flow with heat and friction; shock polars, 1-D unsteady gas dynamics, shock tube, conical flows, methods of characteristics, hypersonic flow theory. Prerequisite: AE 545 or AE 546.

AE 744. Turbulent Flow. 3 Credits.
Reynolds averaged equations for turbulent flow, basic energy relations and spectra in turbulent flow, analysis of turbulent boundary layer, turbulent pipe flow, turbulence models and simulation. Prerequisite: AE 545 or AE 546 or equivalent.

AE 746. Computational Fluid Dynamics. 3 Credits.
Applications of numerical techniques and digital computers to solving fluid flow problems. Solutions involving incompressible and compressible flows, inviscid and viscous flows. Finite difference techniques for different types of partial differential equations governing the fluid flow. Prerequisite: AE 545 or AE 546.

AE 750. Applied Optimal Control. 3 Credits.
Introduction to optimal control analysis and design tools useful for the design of Multi-Input/Multi-Output controllers. Linear Quadratic Regulator problem extended by including advanced command techniques and advanced controller structures. The techniques are illustrated with aerospace applications. Prerequisite: AE 551 or AE 552 or ME 682 or consent of instructor.

AE 752. Linear Multivariable Control. 3 Credits.

An introduction to the modeling and analysis of multi-input, multi-output control systems. Topics include state space representation, solutions of linear systems, stability analysis, LQR design, cooperative controller design, etc. Prerequisite: AE 551 or AE 552, or EECS 444 or equivalent; or by consent of instructor.

AE 753. Digital Flight Controls. 3 Credits.
Introduction to the analysis and design tools useful for the design of aircraft guidance and flight control systems containing continuous dynamics and a digital computer. Topics include Z-plane analysis, autopilot design using successive loop closure, guidance design models, path planning, vision-guided navigation, etc. Prerequisite: AE 551 or AE 552 or ME 682 or consent of instructor.

AE 755. Robust and Nonlinear Control. 3 Credits.
The robustness is one of the most critical qualities of an appropriately designed feedback control system. In this course the ability of the closed-loop system to continue performing satisfactorily despite uncertainties in estimated state variables and/or large variations in the (open-loop) plant dynamics will be investigated. This course will lay down the mathematical and theoretical background needed for the analysis and design of robust feedback control systems. Modern controller design methods (e.g. H-inf control) will be used to design controller highly nonlinear and transient dynamics. Prerequisite: AE 551 or AE 552, AE 750, and MATH 590 or consent of instructor.

AE 759. Estimation and Control of Unmanned Autonomous Systems. 3 Credits.
An introduction to the modeling, estimation, and control of unmanned autonomous systems. Topics include motion description, navigation sensors, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, etc. The successful completion of this course will prepare students for advanced studies in robotics & controls. (Same as EECS 759.) Prerequisite: AE 551 or AE 552 or EECS 444, or by consent of instructor.

AE 765. Orbital Mechanics. 3 Credits.
Motion of space vehicles under the influence of gravitational forces. Two body trajectories, orbit determination, orbit transfer, universal variables, mission planning using patched conics. Transfer orbits. Prerequisite: MATH 220 or MATH 221, and MATH 290 or MATH 291 with a grade of C- or higher, and AE 360 or equivalent.

AE 766. Spacecraft Attitude Dynamics and Control. 3 Credits.
Dynamics of rigid spacecraft, attitude control devices including momentum exchange, mass movement, gravity gradient and reactor rockets. Design of feedback control systems for linear and bang-bang control devices. Prerequisite: AE 551 or AE 552 or permission of instructor.

AE 767. Spacecraft Environments. 3 Credits.
Fundamentals of spacecraft environments. Description and analysis of the natural environment in which spacecraft operate post-launch. Includes optical, electromagnetic, corpuscular radiation, plasma and dust from low Earth orbit, through outer heliosphere. Prerequisite: C- or higher in PHSX 212; PHSX 313 or PHSX 351 recommended.

AE 768. Orbit Determination. 3 Credits.
Develops the theory of batch and sequential (Kalman filter) estimation theory related to orbit estimation, including a review of necessary concepts of probability and statistics. Course work includes a term project that allows students to apply classroom theory to an actual satellite orbit determination problem. Prerequisite: AE 360.

AE 771. Rocket Propulsion. 3 Credits.
Basic elements of rocket propulsion: systems, propellants, and performance. Prerequisite: AE 545 or AE 546 or equivalent.

AE 773. Propulsion Systems for Emerging Aircraft. 3 Credits.
Advanced study of the principles of operation and propulsion systems for UAVs, UAMs and general aviation aircraft. Prerequisite: AE 445, AE 571, ME 212.

AE 774. Introduction to Combustion. 3 Credits.
Study of advanced concepts and principles of combustion, including thermal analysis, chemical reaction, and computational methods. Prerequisite: C- or higher in ME 212, and AE 211 or ME 208 or EECS 138.

AE 790. Special Problems in Aerospace Engineering for Masters Students. 1-5 Credits.
Directed studies of advanced problems in aerospace engineering. Open only to graduate students with departmental approval.

AE 846. Advanced Computational Fluid Dynamics and Heat Transfer. 3 Credits.
Present recent advances in computational fluid dynamics and heat transfer with a focus on numerical algorithms designed for unstructured grids, including grid generation, convergence acceleration techniques, high-order algorithms and parallel computing on CPU and GPU clusters. It is expected that the students will understand the basics of the finite volume method for unstructured grids, and be able to program a 2D Euler solver for arbitrary grids after taking this class. Prerequisite: AE 746. This class is not open to undergraduate students.

AE 892. Special Problems in Aerospace Engineering for Doctoral Students. 1-8 Credits.
Directed studies of advanced problems in aerospace engineering. Open only to graduate students with consent of instructor.

AE 895. M.S. Thesis or Project. 1-6 Credits.
Original research or project which satisfies the requirements for the degree of Master of Science in Aerospace Engineering. Restricted to Aerospace MS students. Graded on a satisfactory progress/limited progress/no progress basis.

AE 996. Ph.D. Dissertation. 1-9 Credits.
Restricted to Aerospace Ph.D. candidates. Graded on a satisfactory progress/limited progress/no progress basis.

AE 997. DE Project. 1-16 Credits.
A major design problem or system study satisfying the project requirements for the Doctor of Engineering in Aerospace Engineering degree. Restricted to Aerospace DE candidates. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Successful completion of Comprehensive Oral Exam.