DEPARTMENT OF AEROSPACE ENGINEERING

Aerospace Engineering
The aerospace engineering discipline involves the design, production, operation, and support of aircraft and spacecraft. Aerospace engineers solve problems, design aircraft and spacecraft, conduct research, and improve processes for the aerospace industry.

Mission
KU aerospace engineering is an international leader in aerospace education and is committed to developing a global community of choice for students, educators, and researchers by strategically aligning teaching, research, and service missions. A world-class graduate and undergraduate education focused on designing, simulating, building, testing, and flying aerospace vehicles is provided. The department invests in research infrastructure and chooses outstanding students, faculty, and staff to conduct basic and applied research of relevance to aerospace vehicles and systems. The department supports the aerospace profession by educating the public, by maintaining the KU aerospace short-course program, and by advising policy-makers in government, industry, and disciplinary professional organizations.

Educational Objectives
Aerospace engineering prepares graduates for professional practice in the aerospace industry and graduate study in aerospace engineering. Achievement is measured through assessment of the performance of graduates three to six years after graduation. Graduates must demonstrate the following measurable learning outcomes:

1. Competence in the analysis, test, and design of aerospace systems and components using contemporary techniques, equipment, and software.
2. An understanding of the professional responsibilities associated with the special public safety and economic aspects of the aerospace industry.
3. The ability to communicate analysis, test, and design results to engineers and nonengineers.
4. The ability to work effectively in interdisciplinary teams.
5. An understanding of the need for lifelong learning.

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 offers the Master of Science and Master of Engineering with a major in aerospace engineering and the Doctor of Philosophy and Doctor of Engineering in aerospace engineering.

Courses
AE 211. Computing for Engineers. 3 Hours.
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 121 or MATH 125. LEC.

AE 221. Introduction to Global History of Aerospace Technologies. 1-3 Hours.
This History of Aerospace Technology starts in neolithic times with a description of a variety of flying implements being used for hunting and warfare. Their basic designs, mechanics, impact on human evolution, migration and societal development are brought forward to the development of gunpowder, ballistics and rocketry. Lighter than air flight innovations from 1783 forward show an intermingling of civil and military uses through WWI, shaping world events and the fortunes of nations. Heavier than air inhabited flight exploration begins with Cayley, includes the contributions of technologists Lilienthal, Chanute, visionaries and writers Mouillard and Verne, and concludes in a vertical exploration by region, nation and manufacturer, including: Douglas, Boeing, Lockheed, Fokker, Heinkel, Messerschmitt, Fairey, Handley Page, Piaggio, Tupelov, Mikoyan-Gurevich, Kamov, Mitsubishi, Hindustan Aeronautics, Sud Aviation and others. This course represents a very unique opportunity for students to study under one of the most important, famous and well published Aerospace Technologists and Historians ever to practice. LEC.

AE 241. Private Flight Course. 1 Hour.
One hour of academic credit is given upon the awarding of the private pilot’s license by the Federal Aviation Administration. Required documentation includes a letter from the F.A.A. designated examiner giving the check ride and a copy of the private license. The Department of Aerospace Engineering provides no ground or flight instruction. Graded on a satisfactory/fail basis. Prerequisite: Aerospace Engineering students only, with consent of instructor. IND.

AE 242. Private Flight Aeronautics. 3 Hours.
Three hours of academic credit is given for the successful completion of the F.A.A. private pilot’s written examination. Required documentation is a copy of the written score. Available only to Aerospace Engineering transfer students as a course substitute for AE 245. IND.

AE 245. Introduction to Aerospace Engineering. 3 Hours.
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 121 or MATH 125. LEC.

AE 290. Aerospace Colloquium. 0.25 Hours.
This is a required course for all aerospace engineering majors each fall semester. Topics of importance and new 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. Technical films. Open enrollment. LEC.

AE 292. Aerospace Industrial Internship. 1 Hour.
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 freshman year. FLD.
AE 345. Fluid Mechanics. 3 Hours.
Study of fundamental aspects of fluid motions and basic principles of gas dynamics with application to the design and analysis of aircraft. Prerequisite: Corequisite: CE 301 or MATH 220. LEC.

AE 360. Introduction to Astronautics. 3 Hours.
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 122 or MATH 126. Corequisite: A course in computer programming. LEC.

AE 390. Aerospace Industrial Internship. 1 Hour.
Engineering internship in an approved company. Internship hours do not satisfy any course requirements for the bachelor's 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 Sophomore year. FLD.

AE 421. Aerospace Computer Graphics. 3 Hours.
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. LEC.

AE 430. Aerospace Instrumentation Laboratory. 3 Hours.
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 and EECS 318. LAB.

AE 441. Advanced Flight Training. 1-3 Hours.
Academic credit is given for the successful completion of advanced flight training beyond the private pilot rating. One hour is given for each of the following: commercial, instrument rating, certified flight instructor. The Aerospace Engineering Department provides no ground or flight instruction. Graded on a satisfactory/fail basis. Open enrollment. Prerequisite: AE 241. IND.

AE 445. Aircraft Aerodynamics and Performance. 3 Hours.
Study of airfoil and wing aerodynamics, component drag, static and special performance, and maneuvers of aircraft. Open enrollment. Prerequisite: AE 345, CE 301. LEC.

AE 490. Aerospace Industrial Internship. 1 Hour.
Engineering internship in an approved company. Internship hours do not satisfy any course requirements for the bachelor's 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. FLD.

AE 507. Aerospace Structures I. 3 Hours.
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. LEC.

AE 508. Aerospace Structures II. 3 Hours.
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 507. LEC.

AE 509. Honors Aerospace Structures. 3 Hours.
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 507. LEC.

AE 510. Aerospace Materials and Processes. 4 Hours.
Properties and applications of aircraft materials, forming methods, and manufacturing processes. Ethics and social responsibility for engineers. Oral technical presentations. Prerequisite: AE 507 and CHEM 130 or CHEM 150. LEC.

Preliminary design project of a complete aircraft system. Technical written reports and oral presentations. Prerequisite: AE 521. LEC.

Preliminary design project of a complete aircraft system. Technical written reports and oral presentations. Prerequisite: AE 521 and AE 560. LEC.

AE 523. Space Systems Design. 4 Hours AE61.
Preliminary design project of a complete space system. Technical written reports and oral presentations. Prerequisite: AE 521. Enrollment only allowed by permission of instructor. LEC.

Preliminary design project of a complete propulsion system, including the airframe. Technical written reports and oral presentations. Prerequisite: AE 521.

AE 545. Fundamentals of Aerodynamics. 4 Hours.
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: AE 445, ME 312, MATH 127 and MATH 220. LEC.

AE 546. Honors Aerodynamics. 5 Hours.
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 312, MATH 220 and MATH 290. LEC.

AE 550. Dynamics of Flight I. 4 Hours.
AE 551. Dynamics of Flight II. 4 Hours.
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 550. LEC.

AE 552. Honors Dynamics of Flight II. 4 Hours.
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 550 and a course in differential equations (MATH 220 or MATH 320). LEC.

AE 560. Spacecraft Systems. 3 Hours.
Fundamentals of spacecraft systems and subsystems. Spacecraft systems engineering, space environment; basic astrodynamics; and the following spacecraft subsystems; attitude determination and control; electrical power; thermal; propulsion; structures and mechanisms; command, telemetry, and data handling; and communications. Prerequisite: AE 360, AE 507, EECS 318, and ME 312. LEC.

AE 571. Fundamentals of Airplane Reciprocating Propulsion Systems. 3 Hours.
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 312. LEC.

AE 572. Fundamentals of Jet Propulsion. 3 Hours.
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. LEC.

AE 573. Honors Propulsion. 3 Hours.
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 and AE 571. LEC.

AE 590. Aerospace Senior Seminar. 1 Hour.
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. LEC.

AE 592. Special Projects in Aerospace Engineering for Undergraduate Students. 1-5 Hours.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor. IND.

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

AE 600. Special Topics: _____. 1-3 Hours.
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. IND.

AE 621. Advanced Aircraft Design Techniques I. 3 Hours.
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. LEC.

AE 628. Wind Turbine Engineering. 3 Hours.
Course will cover the fundamentals of engineering wind-powered electric generators. Topics will include turbine configuration design, drive train engineering, composite rotor blade aerodynamic and structural design, characterizing the influence of the wind conditions on the operation, loads, and performance of a wind turbine, wind turbine controls systems engineering, and power electronic conversion. Prerequisite: AE 508, AE 545, and EECS 316 and EECS 318 or equivalent. LEC.

AE 670. Aerospace Propulsion III. 3 Hours.
Advanced theory of turbojet, fanjet (multi-spool), variable cycle engines, ramjet and bypass air breathing propulsion systems. Theory and design of inlets, compressors, burners and turbines. Component matching, cooling, regenerative systems, test methods and corrections. Prerequisite: AE 572. LEC.

AE 690. Professional Development for Graduate Studies. 0.25 Hours.
Professional development for graduate students. Presentation and discussion of graduate student research. Meets approximately monthly. Each meeting will include either a faculty-guided seminar on one of the core course topics or presentations by students on a research topic. Some class sessions will be devoted to 10-15 minute informal presentations on work in progress. Others will allow students to make informal presentations as a "dress rehearsal" for presentations to be given at a technical conference. Two semesters of enrollment required for all MS, ME PhD and DE aspirants and candidates. Graded on a satisfactory/unsatisfactory basis. LEC.

AE 701. Structural Design. 3 Hours.
Design and internal construction of major structural components: wing, fuselage, empennage, landing gear, engine pylons. Layout of major structures and system interfaces, internal geometry, material alternates, manufacturing alternates and design constraints. Certification and proof of design requirements. Prerequisite: AE 421, AE 508, and AE 510. LEC.

AE 704. Dynamics and Vibrations. 3 Hours.
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. LEC.

AE 705. Structural Vibrations and Modal Testing. 4 Hours.

AE 707. Aerospace Structural Loads. 3 Hours.
Steady state spanwise and chordwise airloads, windshears, gusts, landing gear loads, bird strike, traumatic loads, special commercial and military load requirements. Prerequisite: AE 507 and AE 545. LEC.

AE 708. Aerospace Structures III. 3 Hours.
AE 709. Structural Composites. 3 Hours.
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: CHEM 184 or CHEM 150, CPE 121, AE 508 or CE 761; and AE 510 or ME 346 or CE 710. LEC.

AE 710. Advanced Structural Composites. 3 Hours.
The course objectives are to provide each student with a more in-depth understanding of and practical hands-on experience with available fiber and matrix materials, manufacturing methods, and the mechanical behavior of composite materials and structures. Modern software tools and manufacturing methods are addressed, to include optimization techniques and design for manufacturability. Classical plate theory, bending, buckling, and vibration of anisotropic plates is addressed. Damage tolerance and repairability, as well as nondestructive evaluation techniques are also covered. Skills learned in previous composite courses will be utilized to design, analyze, and fabricate structures of current industrial relevance. Prerequisite: AE 508 or similar, AE 709 or similar, or consent of instructor. LEC.

AE 712. Techniques of Engineering Evaluation. 3 Hours.
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. LEC.

AE 713. Stochastic Systems, Estimation and Identification in Aerospace Engineering. 3 Hours.
Stochastic adaptive control theory is concerned with recursive estimation of unknown parameters and control for systems with uncertainties modeled as random variables or random processes. The theory is motivated by applications in such diverse areas as aerospace guidance and control, signal processing and communications, manufacturing processes, and financial economics. Mathematical theory of stochastic adaptive control for models based on stochastic difference equations such as autoregressive processes and stochastic differential equations as Markov diffusion processes have been developed and will be presented. This course focuses on filtering and system identification theory. Prerequisite: AE 430, AE 550, AE 551, AE 750, MATH 590 and MATH 627 or equivalent. LEC.

AE 721. Aircraft Design Laboratory I. 4 Hours.
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, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently. LAB.

AE 722. Aircraft Design Laboratory II. 4 Hours.
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, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently. LAB.

AE 724. Propulsion System Design and Integration. 3 Hours.
Theory and design of propulsion systems for both low and high speed aircraft and their integration into the overall configuration. Internal and external design and analysis of inlets and nozzles including their effect on the external aerodynamics of the aircraft. Engine/inlet compatibility and the problems of matching both steady state and dynamic characteristics to obtain peak, stable performance. Prerequisite: AE 572. LEC.

AE 725. Numerical Optimization and Structural Design. 3 Hours.
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: MATH 220 and MATH 290 or junior status. LEC.

AE 728. Wind Turbine Engineering. 3 Hours.
Course will cover the fundamentals of engineering wind-powered electric generators. Topics will include turbine configuration design, drive train engineering, composite rotor blade aerodynamic and structural design, characterizing the influence the wind conditions on the operation, loads, and performance of a wind turbine, wind turbine controls systems engineering, and power electronic conversion. Prerequisite: AE 507, AE 545, and EECS 316 and EECS 318 or consent of instructor. LEC.

AE 731. Supersonic Aerodynamics Laboratory. 1 Hour.
Supersonic wind tunnel and shock tube operations, techniques, and instrumentation. Flow study and model testing. Prerequisite: AE 545. LAB.

AE 732. Introduction to Flight Test Engineering. 3 Hours.
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. LEC.

AE 743. Compressible Aerodynamics. 3 Hours.
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. LEC.

AE 744. Introduction to Turbulent Flow. 3 Hours.
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 equivalent. LEC.

AE 745. Applied Wing and Airfoil Theory. 3 Hours.
Applications of potential flow theory to aerodynamics of airfoil sections; wings and wing-body combinations. Introduction to high angle-of-attack and transonic aerodynamics. Prerequisite: AE 545. LEC.
AE 746. Computational Fluid Dynamics. 3 Hours.
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. LEC.

AE 747. Introduction to Transonic Aerodynamics. 3 Hours.
Review of Fundamental Equations, Transonic Similarity Laws, Shock-Expansion Theory, Method of Characteristics (MOC), Aerodynamics of Non-Lifting Bodies, Airfoil Aerodynamics and Aerodynamics of Swept Wings. Prerequisite: AE 545. LEC.

AE 748. Helicopter Aerodynamics. 3 Hours.
Helicopter components and their functioning: rotor aerodynamics, performance, stability and control, aeroelastic effects and vibrations. Prerequisite: AE 551. LEC.

AE 750. Applied Optimal Control. 3 Hours.
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 ME 682 or consent of instructor. LEC.

AE 751. Advanced Airplane Dynamics. 2 Hours.

AE 752. Linear Multivariable Control. 3 Hours.
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, state feedback controller design, LQR design, LQG design, cooperative controller design, etc. The successful completion of this course will prepare students for advanced studies in controls. Prerequisite: AE 551 or equivalent, or EECS 444 or equivalent; or by consent of instructor. LEC.

AE 753. Digital Flight Controls. 3 Hours.
Introduction to the classical Z-plane analysis and design tools useful for the design of control systems containing continuous dynamics and a digital computer. Mathematical modeling of the digital computer and design of digital compensators. Aerospace applications used to demonstrate the concepts. Prerequisite: AE 551 or ME 682 or consent of instructor. LEC.

AE 754. Missile Dynamics. 3 Hours.
Design of missile configurations. General equations of motion. Aerodynamics of missiles in subsonic through hypersonic flight regimes. Theory of missile trajectory. Linear and nonlinear theories of missile flight dynamics. Introduction to guidance and control. Launching problems and free flight dispersions. Prerequisite: AE 551. LEC.

AE 755. Robust and Nonlinear Control. 3 Hours.
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 550, AE 551, AE 750, MATH 590 or consent of instructor. LEC.

AE 756. Rule-Based Control Systems. 3 Hours.
Introduction to rule-based systems with an emphasis on a cognitive architecture. Realistic examples of using such systems will be covered in the context of unmanned aircraft control. A brief review of programming in LISP language, on which the cognitive architecture is based. Prerequisite: EECS 316 and EECS 318, AE 550, AE 551 or equivalent. LEC.

AE 757. Rule-Based UAV Control Lab. 1 Hour.
A guided experience on building an unmanned aircraft system. Uses and existing radio-controlled platform, and thus does not require an expertise in fabrication. Focuses on building the communication hardware and software that enables the use of a rule-based control system on a computer to control the aircraft remotely. Prerequisite: Corequisite: AE 756. LEC.

AE 758. Introduction to Robotics. 3 Hours.
An introduction to robotics covering spatial descriptions and transformations, manipulator kinematics, Jacobians, and dynamics and control of manipulators. The successful completion of this course will prepare students for advanced studies in robotics. Prerequisite: CE 301 or equivalent, AE 551 or equivalent, and MATH 290 or equivalent; or by consent of instructor. LEC.

AE 759. Estimation and Control of Unmanned Autonomous Systems. 3 Hours.
An introduction to the modeling, estimation and control of unmanned autonomous systems. Topics include model identification, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, path planning, etc. The successful completion of this course will prepare students for advanced studies in robotics controls. (Same as EECS 759.) Prerequisite: MATH 627 or EECS 461 or equivalent, AE 551 or EECS 444 or equivalent; or by consent of instructor. LEC.

AE 760. Spacecraft Systems. 3 Hours.
Fundamentals of spacecraft systems and subsystems. Spacecraft systems engineering, space environment; basic astrodynamics; and the following spacecraft subsystems; attitude determination and control; electrical power; thermal; propulsion; structures and mechanisms; command, telemetry, and data handling; and communications. Same as AE 560 with the addition of a research paper. Not available for students that have taken AE 560. Prerequisite: AE 507, EECS 318, MATH 124, and ME 312 or equivalents. LEC.

AE 765. Orbital Mechanics. 3 Hours.
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, MATH 290, and CE 301 or equivalent. LEC.
AE 766. Spacecraft Attitude Dynamics and Control. 3 Hours.
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 permission of instructor. LEC.

AE 767. Spacecraft Environments. 3 Hours.
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: PHSX 212
required, PHSX 313 or PHSX 351 recommended. LEC.

AE 768. Orbit Determination. 3 Hours.
Develops the theory of batch and sequential (Kalman filter) estimation
teaching 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. Corequisite:
AE 560 or AE 760. LEC.

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

AE 772. Fluid Mechanics of Turbomachinery. 3 Hours.
Fundamentals of two- and three-dimensional flows in turbomachinery.
Study of secondary flows and losses. Flow instabilities in axial flow
compressors (stall and surge). Aerodynamic design of a multistage
axial flow compressor. Noise associated with a transonic axial flow
compressor. Turbine blade cooling. Calculation of stresses and blade
life estimation in axial flow turbines. Fundamentals of radial flow
turbomachinery. Prerequisite: AE 572 or consent of instructor. LEC.

AE 781. Introduction to Adaptive Aerostructures. 3 Hours.
This course covers the basic material properties and modeling
techniques for structures that are capable of changing some physical
property in response to a command signal. The course will be useful
for students from nearly every branch of engineering and includes a
fabrication and testing practicum introducing basic post processing and
integration techniques used with piezoelectric, shape memory alloy and
magnetorheological materials. The course concludes with an overview
of applications and examples of adaptive products. Prerequisite: ME 311
or equivalent. LEC.

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

AE 803. Aeroelasticity. 3 Hours.
Introduction to self-excited vibrations, wing flutter, panel flutter, unsteady
aerodynamics, launch vehicle structural vibrations. Prerequisite: AE 508,
AE 545, AE 551, and AE 704. LEC.

AE 821. Advanced Aircraft Design I. 3 Hours.
Aerodynamic design optimization. Aircraft cost prediction methods:
development, manufacturing, and operating. Minimization of operation
costs and implications to configuration design. Design to minimize life-
cycle costs. Design decision making on the basis of cost. LEC.

AE 822. Advanced Aircraft Design II. 3 Hours.
Design of flight control systems, fuel systems, hydraulic systems, and
electrical systems. Weapon system integration problems, design for low
radar cross sections. The kinematics of landing gear retraction systems.
LEC.

AE 830. Aerospace Graduate Internship. 1-12 Hours.
One credit hour per month of approved aerospace engineering internship
satisfying one of the requirements for the MS or PhD program. Graded
on a satisfactory/unsatisfactory basis. INT.

AE 840. Aerodynamics of Viscous Fluids. 3 Hours.
Concepts of boundary layer equations of viscous fluids. Various
transformations for compressible boundary-layer equations. Approximate
and exact finite-difference solutions, including effects of suction and
blowing. Transitions. Concept of turbulent flow and solutions of turbulent
boundary layer equations. Applications in aeronautics. Prerequisite: AE
545. LEC.

AE 845. Transonic Aerodynamics. 3 Hours.
Applications of potential flow, Euler and Navier-Stokes solvers to
transonic and vortex-flow aerodynamics. Concept of rotated finite
difference scheme. Convergence acceleration and multigrid techniques.
Methods of flux vector splitting, upwind differencing, and approximate
factorization. Turbulence modeling. Prerequisite: AE 746. LEC.

AE 846. Advanced Computational Fluid Dynamics and Heat Transfer. 3
Hours.
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. LEC.

AE 850. Advanced Control Seminar. 2 Hours.
Extension of AE 750 covering digital optimal control, optimal estimation,
and advanced control topics. Combination of lecture, seminar, and
project format. Review of current journal articles. Development of
analysis and design computer programs. Prerequisite: AE 750 and
consent of instructor. LEC.

AE 890. ME Internship. 1-6 Hours.
One credit per month of engineering internship. Prerequisite: Admission
to Master of Engineering in Aerospace Engineering program and
approved internship. INT.

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

AE 895. M.S. Thesis or Project. 1-6 Hours.
Original research or project which satisfies the requirements for the
degree of Master of Science in Aerospace Engineering. Restricted to
Aerospace MS students. THE.

AE 896. ME Project. 3-6 Hours.
A design problem or system study satisfying the project requirement for
the Master of Engineering degree in Aerospace Engineering. Prerequisite:
Admission to Master of Engineering in Aerospace Engineering program.
THE.

AE 941. Hypersonic Aerodynamics I. 3 Hours.
The gasdynamics of aerospace vehicles operating in the speed range
above Mach 5. Rarified and dissociated gas flows; magnetogasdynamic
and heat transfer problems. Prerequisite: Consent of instructor. LEC.

AE 990. DE Internship. 1-12 Hours.
One credit per month of engineering internship. Prerequisite: Admission
to DE program and approved internship. INT.
Restricted to Aerospace Ph.D. candidates. Prerequisite: Successful completion of Comprehensive Oral Exam. THE.

AE 997. DE Project. 1-16 Hours.
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. Prerequisite: Successful completion of Comprehensive Oral Exam. THE.