ENAE - ENGINEERING, AEROSPACE

ENAE403 Aircraft Flight Dynamics (3 Credits)
Study of motion of aircraft, equations of motion, aerodynamic force representation, longitudinal and lateral motions, response to controls and to atmospheric disturbances, handling qualities criteria and other figures of merit.
Prerequisite: ENAE414 and ENAE432.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE404 Space Flight Dynamics (3 Credits)
Three-dimensional motion under central fields. Solutions to orbital motion, orbital elements, time elements. Kepler's laws. Orbital maneuvering, rendezvous and station-keeping. Rigid-body attitude dynamics, spacecraft attitude dynamics.
Prerequisite: ENAE301.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE414 Incompressible Aerodynamics (3 Credits)
Aerodynamics of inviscid incompressible flows. Aerodynamic forces and moments. Fluid statics/buoyancy force. Vorticity, circulation, the stream function and the velocity potential. Bernoulli's and Laplace's equations. Flows in low speed wind tunnels and airspeed measurement. Potential flows involving sources and sinks, doublets, and vortices. Development of the theory of airfoils and wings.
Prerequisite: PHYS271, (MATH240 or MATH461), PHYS270, MATH246, ENAE283, ENES220, ENAE202, MATH241, and ENES232.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department; and junior standing or higher.

ENAE415 Helicopter Theory (3 Credits)
Elementary exposition on the theory and practice of aerodynamics applied to helicopters and other rotary wing aircraft.
Prerequisite: ENAE414.
Restriction: Must be in Engineering: Aerospace program.

ENAE420 Computational Structural Mechanics (3 Credits)
Introductory of finite element methods for aerospace engineering modeling and analysis; equips students with ability to understand manuals of commercial finite element analysis software.
Prerequisite: ENES220 and MATH241; and must have completed a course in linear algebra.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE423 Vibration and Aeroelasticity (3 Credits)
Dynamic response of single and multiple degrees of freedom systems, finite element modeling, wing divergence, aileron reversal, wing and panel flutter.
Prerequisite: ENAE324.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE425 Mechanics of Composite Structures (3 Credits)
Introduction to structures composed of composite materials and their applications in aerospace. In particular, filamentary composite materials are studied. Material types and fabrication techniques, material properties, micromechanics, anisotropic elasticity, introduction to failure concepts.
Prerequisite: MATH246, ENAE324, ENES220, and MATH241.

ENAE432 Control of Aerospace Systems (3 Credits)
An introduction to the feedback control of dynamic systems. Laplace transforms and transfer function techniques; frequency response and Bode diagrams. Stability analysis via root locus and Nyquist techniques. Performance specifications in time and frequency domains, and design of compensation strategies to meet performance goals.
Prerequisite: Minimum grade of C- in ENAE301 and ENAE283.
Restriction: Junior standing or higher; and must be in Engineering: Aerospace program.

ENAE441 Space Navigation and Guidance (3 Credits)
Principles of navigation. Celestial, radio, and inertial navigation schemes. Navigational and guidance requirements for orbital, planetary, and atmospheric entry missions. Fundamentals of communications and information theory. Link budgets, antennas and telemetry systems.
Prerequisite: ENAE404 and ENAE432.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE450 Robotics Programming (3 Credits)
Introduces students to the Robot Operating System (ROS) as well as to many of the available tools commonly used in robotics. Lectures focus on theory and structure, whereas laboratory sections will focus on applications and implementations. Students learn how to create software and simulations, interface to sensors and actuators, and integrate control algorithms. The course works through exercises involving a number of autonomous robots (i.e., ground and air vehicles) that students will eventually use in their subsequent RAS minor courses. Topics include: ROS architecture, console commands, ROS packages, simulation environments, visualizations, autonomous navigation, manipulation, and robot vision.
Prerequisite: ENME480 or ENAE380.
Restriction: Must be in the Robotics and Autonomous Systems (RAS) minor; or permission of department.
Additional Information: Students in the Robotics and Autonomous Systems minor should take ENME480 as a prerequisite; Aerospace Engineering students not in the minor should take ENAE380.

ENAE455 Aircraft Propulsion and Power (3 Credits)
Thermodynamic cycle analysis, aerothermochemistry of fuels and propellants, operating principles of piston, turbojet, fanjet, and other variations of airbreathing aircraft power units.
Prerequisite: ENES232, ENAE414, and ENAE311.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE457 Space Propulsion and Power (3 Credits)
Thermodynamic cycle analysis, aerothermochemistry of fuels and propellants, operating principles of rocket, ion, and other exoatmospheric power units.
Prerequisite: PHYS271, ENES232, PHYS270, and ENAE311.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department. And senior standing.

ENAE464 Aerospace Engineering Laboratory (3 Credits)
Application of fundamental measuring techniques to measurements in aerospace engineering. Includes experiments in aerodynamics, structures, propulsion, flight dynamics and astrodynamics. Correlation of theory with experimental results.
Prerequisite: ENAE324, ENAE362, ENAE311, and ENAE432.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE467 Advanced Space Propulsion and Power (3 Credits)
Charged particle motion, drift mechanisms, plasma sheaths, creation of plasmas. Representative electrothermal, electrostatic, and electromagnetic propulsion technologies. Power production and direct-drive thrust generation using fusion as time permits.
Prerequisite: ENAE457.
Restriction: Permission of Instructor. Jointly offered with: ENAE667.
Credit Only Granted for: ENAE488I, ENAE467, or ENAE667.
Formerly: ENAE488I.

ENAE471 Aircraft Flight Testing (3 Credits)
Provides basic instruction to aircraft flight testing and demonstrates need for systematic, well-proven technique to allow for accurate airplane performance. Concepts of aerodynamics, airplane performance, and stability and control. Emphasis on single-engine general aviation type aircraft.
Prerequisite: ENAE414.
Corequisite: ENAE403.
Restriction: Must be in Engineering: Aerospace program.

ENAE481 Principles of Aircraft Design (3 Credits)
Aircraft design principles blending both synthesis and analysis. The iterative nature of the design process. Applied aerodynamics. Elements of aircraft performance calculation and optimization. Design of aircraft including payload, crew and avionics provisions, propulsion selection and sizing, aerodynamic configuration optimization, mass properties, stability and control characteristics, and vehicle subsystems. Individual student projects in aircraft design.
Prerequisite: ENAE324, ENAE362, and ENAE432.
Corequisite: ENAE414.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE482 Aeronautical Systems Design (3 Credits)
Senior capstone design course in the aeronautics track. Introduction of computerized methods for sizing and performance analysis. More comprehensive methods to predict weight, aerodynamics and propulsion system characteristics. Consideration in design disciplines such as vulnerability, maintainability, produceability, etc. Groups of students will complete, brief and report on a major design study to specific requirements.
Prerequisite: ENAE455, ENAE423, ENAE403, and ENAE481.
Restriction: Must be in Engineering: Aerospace program; and senior standing or higher.

ENAE483 Principles of Space Systems Design (3 Credits)
Principles of space systems analysis and vehicle design. Launch vehicle performance analysis and optimization. Design of vehicle systems including avionics, power, propulsion, life support, human factors, structures, actuator and mechanisms, and thermal control. Design processes and design synthesis. Individual student projects in vehicle design.
Prerequisite: ENAE404, ENAE324, ENAE362, and ENAE432.
Restriction: Must be in Engineering: Aerospace program; or permission of ENGR-Aerospace Engineering department.

ENAE484 Space Systems Design (3 Credits)
Senior capstone design course in the space track. Group preliminary design of a space system, including system and subsystem design, configuration control, costing, risk analysis, and programmatic development. Course also emphasizes written and oral engineering communications.
Prerequisite: ENAE423, ENAE483, ENAE441, and ENAE457.
Restriction: Must be in Engineering: Aerospace program.

ENAE488 Topics in Aerospace Engineering (1-4 Credits)
Technical elective taken with the permission of the student's advisor and instructor. Lecture and conference courses designed to extend the student's understanding of aerospace engineering. Current topics are emphasized.
Prerequisite: Permission of student's advisor required.
Restriction: Permission of instructor.

ENAE499 Elective Research (3 Credits)
Undergraduate research project and paper conducted under the direction of an aerospace engineering faculty member to be presented at a conference or competition.
Prerequisite: Permission from student's advisor required.
Restriction: Senior standing or higher; and must be in Engineering: Aerospace program; and permission of instructor; and permission of ENGR-Aerospace Engineering department.
Repeatable to: 6 credits if content differs.

ENAE601 Astrodynamics (3 Credits)
Mathematics and applications of orbit theory, building upon the foundations developed in ENAE 404 and ENAE 441. Topics include two body orbits, solutions of Kepler's equation, the two-point boundary value problem, rendezvous techniques, and Encke's method.
Prerequisite: ENAE404; or permission of ENGR-Aerospace Engineering department.

ENAE602 Spacecraft Attitude Dynamics and Control (3 Credits)
Rigid body rotational dynamics of spacecraft; forced and unforced motion, torques produced by the orbital environment; orbit/attitude coupling; gas jet, momentum wheel, and magnetic torque actuators. Elementary feedback attitude regulators and algorithms for linear and nonlinear attitude tracking.
Prerequisite: ENAE404 and ENAE432.

ENAE603 Near-Earth Object Exploration (3 Credits)
An overview of the near-Earth objects (NEOs) of our solar system--the asteroids and comets whose orbits closely approach Earth's orbit--and what we know about them, what we're learning about them, and how to design spacecraft missions to interact with them.
Prerequisite: ENAE601.
Restriction: Must be in one of the following programs (ENGR: MS/PhD-Aerospace Engineering (Master's); ENGR: MS/PhD-Aerospace Engineering (Doctoral)).
Credit Only Granted for: ENAE788N or ENAE603.
Formerly: ENAE788N.

ENAE631 Helicopter Aerodynamics I (3 Credits)
A history of rotary-wing aircraft, introduction to hovering theory, hovering and axial flight performance, factors affecting hovering and vertical flight performance, autorotation in vertical descent, concepts of blade motion and control, aerodynamics of forward flight, forward flight performance, operational envelope, and introduction to rotor acoustics.
Prerequisite: ENAE414 and ENAE311. Or permission of ENGR-Aerospace Engineering department; and permission of instructor.

ENAE632 Helicopter Aerodynamics II (3 Credits)
Basic aerodynamic design issues associated with main rotors and tail rotors, discussion of detailed aerodynamic characteristics of rotor airfoils, modeling of rotor airfoil characteristics, review of classical methods of modeling unsteady aerodynamics, the problem of dynamic stall, review of methods of rotor analysis, physical description and modeling of rotor vortical wakes, discussion of aerodynamic interactional phenomena on rotorcraft, advanced rotor tip design, physics and modeling of rotor acoustics.
Prerequisite: ENAE631; and (ENAE414 and ENAE311; or students who have taken courses with comparable content may contact the department). Or permission of ENGR-Aerospace Engineering department.

ENAE633 Helicopter Dynamics (3 Credits)
Flap dynamics. Mathematical methods to solve rotor dynamics problems. Flap-lag-torsion dynamics and identify structural and inertial coupling terms. Overview on rotary wing unsteady aerodynamics. Basic theory of blade aeroelastic stability and ground and air resonance stability, vibration analyses and suppression.
Prerequisite: ENAE631. Or permission of ENGR-Aerospace Engineering department; and permission of instructor.

ENAE634 Helicopter Design (3 Credits)
Principles and practice of the preliminary design of helicopters and similar rotary wing aircrafts. Design trend studies, configuration selection and sizing methods, performance and handling qualities analyses, structural concepts, vibration reduction and noise. Required independent design project conforming to a standard helicopter request for proposal (RFP).
Prerequisite: ENAE631. Or permission of ENGR-Aerospace Engineering department; and permission of instructor.

ENAE635 Helicopter Stability and Control (3 Credits)
Advanced dynamics as required to model rotorcraft for flight dynamic studies. Development of helicopter simulation models and specifications of handling qualities. Methods for calculation of trim, poles, frequency response, and free flight response to pilot inputs.
Prerequisite: ENAE631.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE636 Helicopter Dynamics II (3 Credits)
Aerodynamics, dynamics and aeromechanics of helicopters and tilt rotor aircraft. Experimental testing and mathematical modeling required for the design and analysis of such aircraft.
Credit Only Granted for: ENAE788R or ENAE636.
Formerly: ENAE788R.

ENAE641 Linear System Dynamics (3 Credits)
Linear systems; state space, multi-input, multi-output models; eigenstructure; controllability, observability, singular value analysis; multivariable Nyquist condition; observer design; introduction to Kalman filtering. Full state feedback techniques including pole placement and LQR/LQG techniques; introduction to loop shaping and robustness.
Prerequisite: ENAE432.

ENAE642 Atmospheric Flight Control (3 Credits)
Exposure to flight guidance and control. Draws heavily from vehicle dynamics as well as feedback theory, and careful treatment of the non-linear aspects of the problem is critical. Conventional sythesis techniques are stressed, although modern methods are not ignored. Multivariable system analysis is included, along with flight-control design objectives and hardware limitations. Emphasis on aircraft and missiles.
Prerequisite: ENAE403 and ENAE432; or students who have taken courses with comparable content may contact the department.

ENAE646 Advanced Dynamics of Aerospace Systems (3 Credits)
Introduces the principles and methods for formulating and analyzing mathematical models of aerospace systems using Newtonian, Lagrangian, and Hamiltonian formulations of particle and rigid body dynamics. Additional topics include applied dynamical systems, geometric mechanics, and symmetry and reduction.
Prerequisite: ENAE301.
Credit Only Granted for: ENAE788G or ENAE646.
Formerly: ENAE788G.

ENAE647 Flexible Multi-body Dynamics (3 Credits)
Review of particle dynamics, rigid body kinematics, analytical dynamics, constraint equations in multibody dynamics, methods for enforcing kinematic constraint, formulation of flexible bodies in multibody dynamics, finite element modeling, and numerical integration methods.
Prerequisite: ENAE646.
Restriction: Must be in one of the following programs (ENGR: MS/PhD-Aerospace Engineering (Doctoral); ENGR: MS/PhD-Aerospace Engineering (Master's)).
Credit Only Granted for: ENAE788Q or ENAE647.
Formerly: ENAE788Q.

ENAE651 Smart Structures (3 Credits)
Topics related to the analysis, design, and implementation of smart structures and systems: modeling of beams and plates with induced strain actuation; shape memory alloys; electro-rheological fluids; magnetostrictor and electrostricter actuators and fiber optic sensors.

ENAE652 Computational Structural Mechanics (3 Credits)
Fundamentals of structural mechanics and computational modeling. Finite element modeling of two- and three-dimensional solids, plates and shells. Geometrically nonlinear behavior. Structural stability such as buckling and postbuckling.
Restriction: Permission of instructor; and permission of ENGR-Aerospace Engineering department.
Credit Only Granted for: ENME 674, ENAE652, ENPM652 or ENPM808F.

ENAE653 Nonlinear Finite Element Analysis of Continua (3 Credits)
Finite element formulation of nonlinear and time dependent processes. Introduction to tensors, nonlinear elasticity, plasticity and creep. Application to nonlinear solids including aerospace structures, such as shells undergoing finite rotations.
Prerequisite: ENAE652; or students who have taken courses with comparable content may contact the department.

ENAE654 Mechanics of Composite Structures (3 Credits)
An introduction to structures composed of composite materials and their applications in aerospace. In particular, filamentary composite materials are studied. Material types and fabrication techniques, material properties, micromechanics, anisotropic elasticity, introduction to failure concepts.

ENAE655 Structural Dynamics (3 Credits)
Advanced principles of dynamics necessary for structural analysis; solutions of eigenvalue problems for discrete and continuous elastic systems, solutions to forced response boundary value problems by direct, modal, and transform methods.

ENAE656 Aeroelasticity (3 Credits)
Topics in aeroelasticity: wing divergence; aileron reversal; flexibility effects on aircraft stability derivatives; wing, empennage and aircraft flutter; panel flutter; aircraft gust response; and aeroservoelasticity of airplanes.
Prerequisite: ENAE655.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE663 Introduction to Plasmas for Space Propulsion and Power (3 Credits)
Characteristics of plasmas, motion of charged particles in fields, collisional processes, kinetic theory, fluid desctiption of plasmas, transpot properties, equilibrium vs. non-equilibrium, generation of plasmas.
Recommended: PHYS270 or equivalent.

ENAE665 Advanced Airbreathing Propulsion (3 Credits)
Advanced treatment of airbreathing propulsion technologies, propulsion system analysis, and engine/airframe integration. Topics will vary, but may include novel engine cycles, advanced gas turbine systems, pulsed systems, and high-speed engines, including scramjets and combined cycle systems.
Prerequisite: ENAE455; or students who have taken courses with comparable content may contact the department.
Restriction: Permission of instructor.

ENAE667 Advanced Space Propulsion and Power (3 Credits)
Charged particle motion, drift mechanisms, plasma sheaths, creation of plasmas. Representative electrothermal, electrostatic, and electromagnetic propulsion technologies. Power production and direct-drive thrust generation using fusion as time permits.
Prerequisite: ENAE457 or equivalent.
Restriction: Permission of instructor. Jointly offered with: ENAE467.
Credit Only Granted for: ENAE488I, ENAE467, or ENAE667.

ENAE673 Aerodynamics of Incompressible Fluids (3 Credits)
Introduces the fundamental concepts of incompressible flows. Topics to be addressed include the conservation equations, potential flow, lift and drag, Navier-Stokes equations, boundary layers and similarity solutions, and solutions to classical problems.
Prerequisite: Undergraduate courses in differential equations, incompressible, and compressible flow (ENAE311; and one course from ENAE414; ENME331, OR ENME640, or equivalent).
Restriction: Must be in ENGR: MS/PhD-Aerospace Engineering (Master's) program.

ENAE674 Aerodynamics of Compressible Fluids (3 Credits)
One-dimensional flow of a perfect compressible fluid. Shock waves. Two-dimensional linearized theory of compressible flow. Two-dimensional transonic and hypersonic flows. Exact solutions of two-dimensional isotropic flow. Linearized theory of three-dimensional potential flow. Exact solution of axially symmetrical potential flow. One-dimensional flow with friction and heat addition.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE675 Unsteady Aerodynamics (3 Credits)
Classical theories of incompressible unsteady aerodynamics with an introduction to modeling techniques. Topics include: unsteady Bernoulli's equation, added mass, the indicial response method, dynamic stall, and modern applications.
Prerequisite: ENAE414; and permission of instructor.
Credit Only Granted for: ENAE672 or ENAE675.
Formerly: ENAE672.

ENAE676 Turbulence (3 Credits)
Physical and statistical descriptions of turbulence; review of phenomenological theories for turbulent flows; scales of motion; correlations and spectra; homogeneous turbulent flows; inhomogeneous shear flows; turbulent flows in pipes and channels; turbulent boundary layers; theory of methods for turbulent flows (Reynolds stress equations, LES, DES, DNS); experimental methods for turbulence measurements.
Prerequisite: ENAE673.
Recommended: ENAE674.

ENAE681 Engineering Optimization (3 Credits)
Methods for unconstrained and constrained minimization of functions of several variables. Sensitivity analysis for systems of algebraic equations, eigenvalue problems, and systems of ordinary differential equations. Methods for transformation of an optimization problem into a sequence of approximate problems. Optimum design sensitivity analysis.

ENAE682 Hypersonic Aerodynamics (3 Credits)
Hypersonic shock and expansion waves, Newtonian theory, Mach methods, numerical solutions to hypersonic inviscid flows, hypersonic boundary layer theory, viscous interactions, numerical solutions to hypersonic viscous flows. Applications to hypersonic vehicles.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE683 High Temperature Gas Dynamics (3 Credits)
Aspects of physical chemistry and statistical thermodynamics necessary for the analysis of high temperature flows, equilibrium and nonequilibrium chemically reacting flows, shock waves, nozzle flows, viscous chemically reacting flow, blunt body flows, chemically reacting boundary layers, elements of radiative gas dynamics and applications to hypersonic vehicles.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE684 Computational Fluid Dynamics I (3 Credits)
Partial differential equations applied to flow modelling, fundamental numerical techniques for the solution of these equations, elliptic, parabolic, and hyperbolic equations, elements of finite difference solutions, explicit and implicit techniques. Applications to fundamental flow problems.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE685 Computational Fluid Dynamics II (3 Credits)
Continuation of ENAE 684. Basic algorithms for the numerical solution of two and three dimensional inviscid and viscous flows. Applications to internal and external flow problems.
Prerequisite: ENAE684.
Restriction: Permission of ENGR-Aerospace Engineering department.

ENAE688 Seminar (1-3 Credits)

ENAE691 Satellite Design (3 Credits)
Systems design of Earth-orbiting satellites, including geostationary communications satellites and low Earth orbit constellations. Basics of orbital motion, communications, and instrument design. Spacecraft systems, structural design, thermal design, power generation, and attitude determination and control. Launch vehicle interfacing and mission operations.
Prerequisite: ENAE483.

ENAE692 Introduction to Space Robotics (3 Credits)
Introduction to the kinematics, dynamics, and control of robot manipulators. DH parameters, serial and parallel manipulators, kinematic redundancy, sensors, actuators, and mechanism design. Control concepts introduced ranging from independent joint control to impedance control. Examples drawn from space robotics, wearable robotics, and other areas.
Prerequisite: ENAE301 or ENES221.
Recommended: ENAE432.

ENAE694 Spacecraft Communications (3 Credits)
Brief overview of satellite orbits. Radio frequency communications, noise, and bandwidth limitations. Link budget analysis. Modulation and multiplexing approaches, multiple access systems. Satellite transponder and Earth station technology.

ENAE696 Spacecraft Thermal Design (3 Credits)
Thermal sources in space. Black-body radiation; absorptivity and emissivity; radiative thermal equilibrium. Mutually radiating plates, view angles, and interior conduction. Techniques of spacecraft thermal analysis; approaches to passive and active thermal control.

ENAE697 Space Human Factors and Life Support (3 Credits)
Engineering requirements supporting humans in space. Life support design: radiation effects and mitigation strategies; requirements for atmosphere; water, food, and temperature control. Accommodations for human productivity in space: physical and psychological requirements; work station design; and safety implication of system architectures. Design and operations for extra-vehicular activity.

ENAE741 Interplanetary Navigation and Guidance (3 Credits)
Interplanetary trajectory construction; patched and multiconic techniques. Methods of orbit and attitude determination; applied Kalman filtering. Guidance algorithms and B-plane targeting. Interplanetary navigation utilizing in situ and radio techniques.
Prerequisite: ENAE601 and ENAE432.

ENAE742 Robust Multivariable Control (3 Credits)
Limitations on achievable performance in multivariable feedback systems due to uncertainty. Singular values, matrix norms, multivariable Nyquist stability theory, uncertainty modeling in aerospace systems. Loop-shaping, generalization of Bode design principles. Characterizing the uncertainty, robustness and performance analysis, and synthesis, primarily in the frequency domain. Current research directions. Aerospace examples are used to complement the theory.
Prerequisite: ENAE641.

ENAE743 Applied Nonlinear Control of Aerospace Systems (3 Credits)
Mathematics and methods of nonlinear systems analysis and nonlinear control design, including nonlinear models and phenomena, Lyapunov stability, input-output stability, passivity and frequency domain analysis, nonlinear controllability and observability, feedback linearization, sliding mode control, and integrator backstepping.
Prerequisite: ENAE641.

ENAE757 Advanced Structural Dynamics (3 Credits)
Demonstrate the practical application of Smart Materials and Spatially Distributed Transducers to the design and control of advanced structures. The course will be focused toward the active control of continuum structures using advance Spatially Distributed Parameter System control techniques and concepts. Effective system parameterizations will be used to reduce distributed parameter system models to classical canonical state space form for the purpose of robust adaptive structure design. Application case studies, including morphing structures will be employed as necessary to enhance the students intuition and understanding of Distributed Parameter Systems.
Prerequisite: ENAE655; or students who have taken courses with comparable content may contact the department.

ENAE788 Selected Topics in Aerospace Engineering (1-3 Credits)

ENAE791 Launch and Entry Vehicle Design (3 Credits)
Design of aerospace vehicles for atmospheric transit to and from space. Generic formulation of atmospheric flight dynamics. Ballistic and lifting entry trajectories. Estimation of vehicle aerodynamic properties and aerothermodynamic heating. Entry thermal protection design. Trajectory analysis of sounding rockets and orbital launch vehicles. Serial, parallel, and hybrid multistaging schemes, optimal multistaging. Constrained trajectory optimization. Launch vehicle economic and reliability analysis, flight termination systems, sensors and actuators.
Prerequisite: ENAE601.

ENAE799 Master's Thesis Research (1-6 Credits)

ENAE898 Pre-Candidacy Research (1-8 Credits)

ENAE899 Doctoral Dissertation Research (1-8 Credits)