AEROSPACE ENGINEERING

Undergraduate Study

For undergraduate curriculum in aerospace engineering leading to the degree bachelor of science. The Aerospace Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org/.

The aerospace engineer is primarily concerned with the design, analysis, testing, and overall operation of vehicles which operate in air and space. The curriculum is designed to provide the student with an education in the fundamental principles of aerodynamics, flight dynamics, propulsion, structural mechanics, flight controls, design, testing, and space technologies. A wide variety of opportunities awaits the aerospace engineering graduate in research, development, design, production, sales, and management in the aerospace industry, and in many related industries in which fluid flow, control, structural, and transportation challenges play major roles.

Make To Innovate (M:2:I) is an exciting new program in the Aerospace Engineering Department that engages students in hands-on projects to augment their understanding of engineering fundamentals.

A cooperative education program in aerospace engineering is available in cooperation with government agencies and industry. The usual four-year curriculum is extended for students who participate in alternating industrial experience periods and academic periods. This arrangement offers valuable practical experience and financial assistance during the college years.

Undergraduate Mission and Educational Objectives

The Department of Aerospace Engineering maintains an internationally recognized academic program in aerospace engineering via ongoing consultation with students, faculty, industry, and aerospace professionals. Results of these consultations are used in a process of continuous academic improvement to provide the best possible education for our students.

Mission statement:

The mission of the aerospace engineering program is to prepare the aerospace engineering student for a career with wide-ranging opportunities in research, development, design, production, sales, and management in the aerospace industry and in the many related industries which are involved with the solution of multi-disciplinary, advanced technology problems.

Program Educational Objectives:

The objectives of the Aerospace Engineering program at ISU are to produce graduates:

- Who actively contribute to the field of aerospace, related fields or other disciplines;
- Are critical thinkers and lifelong learners; and
- Are aware of the societal, economic and environmental impact of their work.

Curriculum in Aerospace Engineering

Leading to the degree bachelor of science.

Total credits required: 129.0.

Any transfer credit courses applied to the degree program require a grade of C or better (but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA). See also Basic Program and Special Programs. Note: Department does not allow Pass/Not Pass credits to be used to meet graduation requirements for either required or elective courses.

International Perspectives [1]: 3 cr.
U.S. Diversity [1]: 3 cr.
Communication Proficiency/Library requirement:

ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
LIB 160	Information Literacy	1
One of the following:		3
ENGL 314	Technical Communication (C or better in this course)	
ENGL 309	Proposal and Report Writing (C or better in this course)	

General Education Electives: 12.0 cr. [2]

Complete 12 cr. General Education Electives are requirements for graduation so may not be taken on a P-NP basis.

Basic Program: 24 cr.

A minimum GPA of 2.00 required for this set of courses (please note that transfer course grades will not be calculated into the Basic Program GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

CHEM 167	General Chemistry for Engineering Students	4
or CHEM 177	General Chemistry I	
ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGR 101	Engineering Orientation	R
AER E 160	Aerospace Engineering Problems With Computer Applications Laboratory [3]	3
LIB 160	Information Literacy	1
MATH 165	Calculus I	4

MATH 166	Calculus II	4
PHYS 221	Introduction to Classical Physics I	5
Total Credits		**24**

Math and Physical Science: 13 cr.

MATH 265	Calculus III	4
MATH 267	Elementary Differential Equations and Laplace Transforms	4
PHYS 232	Introduction to Classical Physics II	4
PHYS 232L	Introduction to Classical Physics II Laboratory	1
Total Credits		**13**

Aerospace Engineering Core: 47 cr.

A minimum GPA of 2.00 required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Core GPA):

AER E 261	Introduction to Performance and Design	3
AER E 310	Aerodynamics I: Incompressible Flow	3
AER E 311	Aerodynamics II: Compressible Flow	3
AER E 321	Flight Structures Analysis	3
AER E 331	Flight Control Systems I	3
AER E 322	Aerospace Structures Laboratory	2
AER E 344	Aerodynamics and Propulsion Laboratory	3
AER E 351	Astrodynamics I	3
AER E 355	Aircraft Flight Dynamics and Control	3
AER E 411	Aerospace Vehicle Propulsion	3
AER E 415	Rocket Propulsion	3
or AER E 433	Spacecraft Dynamics and Control	
AER E 421	Advanced Flight Structures	3
AER E 461	Modern Design Methodology with Aerospace Applications	3
AER E 462	Design of Aerospace Systems	3
E M 324	Mechanics of Materials	3
M E 231	Engineering Thermodynamics I	3
Total Credits		**47**

Other Remaining Courses: 33 cr.

ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
C E 274	Engineering Statics	3
M E 345	Engineering Dynamics	3
MAT E 273	Principles of Materials Science and Engineering	3
AER E 161	Numerical, Graphical and Laboratory Techniques for Aerospace Engineering	3
AER E 361	Computational Techniques for Aerospace Design	3
AER E 362	Aerospace Systems Integration	3
3 credits from the following		3
any AER E or EM graduate level (500+ level) course		
AER E 407	Applied Formal Methods	
AER E 412	Spacecraft Electric Propulsion	
AER E 415	Rocket Propulsion	
AER E 417	Experimental Mechanics	
AER E 422	Vibrations and Aeroelasticity	
AER E 423	Composite Flight Structures	
AER E 426	Design of Aerospace Structures	
AER E 432	Flight Control Systems II	
AER E 433	Spacecraft Dynamics and Control	
AER E 442	V/STOL Aerodynamics and Performance	
AER E 446	Computational Fluid Dynamics	
AER E 448	Fluid Dynamics of Turbomachinery	
AER E 451	Astrodynamics II	
AER E 463	Introduction to Multidisciplinary Design Optimization	
AER E 464	Spacecraft Systems	
AER E 468	Large-Scale Complex Engineered Systems (LSCES)	
AER E 481	Advanced Wind Energy: Technology and Design	
AER E 483	Aeroacoustics	
One of the following:		3
ENGL 314	Technical Communication (Must have a C or better in this course)	
ENGL 309	Proposal and Report Writing (Must have a C or better in this course)	
Technical Electives (see below) [2]		3
Career Electives (see below) [2]		3
Total Credits		**33**

Technical Electives, 3 cr. and Career Electives, 6 cr. selected from preceding Aer E list or departmental-approved 300-level or above courses relevant to technical and career areas.

Seminar/Co-op/Internships/Flight Experience:

AER E 192	Aerospace Seminar	R
AER E 301	Flight Experience	R

Co-op and internships are optional

1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also allowed by the department to meet other course requirements within the degree program. U.S. diversity and international perspectives courses may not be taken Pass/Not Pass.

2. Choose from department approved list. (http://www.aere.iastate.edu/students/undergraduate_program/)
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.

See also: A 4-year plan of study grid showing course template by semester. (http://catalog.iastate.edu/previouscatalogs/2021-2022/collegeofengineering/aerospaceengineering/#fouryearplantext)

Aerospace Engineering, B.S.

Freshman

Fall	Credits	Spring	Credits
MATH 165	4	MATH 166	4
CHEM 167	4	PHYS 221	5
AER E 160	3	AER E 161	3
LIB 160	1	General Education Elective	3
ENGL 150	3	AER E 192	R
ENGR 101	R		
	15		**15**

Sophomore

Fall	Credits	Spring	Credits
MATH 265	4	MATH 267	4
AER E 261	3	M E 345	3
PHYS 232	4	MAT E 273	3
PHYS 232L	1	E M 324	3
C E 274	3	ENGL 314 or 309	3
ENGL 250	3		
	18		**16**

Junior

Fall	Credits	Spring	Credits
AER E 321	3	AER E 421	3
AER E 322	2	AER E 361	3
M E 231	3	AER E 362	3
AER E 310	3	AER E 344	3
AER E 351	3	AER E 311	3
AER E 355	3	AER E 331	3
AER E 301	R		
	17		**18**

Senior

Fall	Credits	Spring	Credits
Technical Elective	3	Technical Elective	3
AER E 461	3	Technical Elective	3
AER E 411	3	AER E 462	3
AER E 415 or 433	3	General Education Elective	3
General Education Elective	3	General Education Elective	3
	15		**15**

Nondestructive Evaluation (NDE)

The NDE Minor (http://catalog.iastate.edu/previouscatalogs/2021-2022/collegeofengineering/non_destructiveevaluationengineering/) is multidisciplinary and open to undergraduates in the College of Engineering.

Graduate Study

The department offers graduate programs that lead to the degrees master of engineering, master of science, and doctor of philosophy with major in aerospace engineering and minor work to students taking major work in other departments. For all graduate degrees, it is possible to establish a co-major program with another graduate degree-granting department. Within the aerospace program, students can specialize in one or more of the following areas: aerospace systems design, atmospheric and space flight dynamics, computational fluid dynamics, control systems, wind engineering, fluid mechanics, optimization, structural analysis, and non-destructive evaluation.

Master of Science and Master of Engineering

The Master of Science degree requires a thesis and has strong research emphasis. The Master of Science degree is recommended for students who anticipate entering a doctoral program later. The Master of Engineering degree does not require either research credits or a thesis and is intended for students who do not anticipate pursuing a doctoral degree. The Master of Engineering degree can be completed with coursework only or with a combination of coursework and creative component. Credits for creative component will be obtained by registering for **AerE 599 Creative Component.** A written report and an oral presentation will be given to the student's graduate committee.

At least 30 credits of acceptable graduate work are required for both the Master of Science and the Master of Engineering degrees. For specific course, research, and creative component requirements, see the departmental Graduate Student Handbook (http://www.aere.iastate.edu/files/2015/04/AerE-Graduate-Handbook-Revised-S15.pdf).

Bachelor of Science/Master of Science Concurrent Degree Program

The department offers concurrent BS/MS and BS/ME degree programs (http://www.aere.iastate.edu/students/concurrent-degrees/) and a concurrent BS/MBA degree program which offer an opportunity for well-qualified Iowa State juniors and seniors to begin working on a master's degree before completing a bachelor's degree. The concurrent degree programs reduce by one year the normal time period for completing both degrees separately.

Preparation for Graduate Work

The normal prerequisite for major graduate work in aerospace engineering is the completion of an undergraduate curriculum substantially equivalent to that required of aerospace engineering students at this university. Due to the diversity of interests of aerospace faculty, students whose prior undergraduate or graduate education has been in allied engineering and/or scientific fields may also qualify. In such cases, it may be necessary for the student to take additional work to provide the requisite aerospace background. A prospective graduate student is urged to specify the degree program and the specific field(s) of interest on the application for admission.

Courses are offered at the times stated in the course description. Where no specific time of offering is stated, the course may be offered during any semester provided there is sufficient demand.

Graduate Minor Work

Minor work for aerospace engineering majors is usually selected from mathematics, physics, electrical engineering, engineering mechanics, mechanical engineering, materials science, meteorology, computer science, and computer engineering.

Courses primarily for undergraduates:

AER E 160: Aerospace Engineering Problems With Computer Applications Laboratory
(2-2) Cr. 3. F.S.
Prereq: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165
Solving aerospace engineering problems and presenting solutions through technical reports. Significant figures and estimation. SI units. Graphing and curve fitting. Introduction to aerospace engineering and engineering design. Spreadsheet programs. History of aerospace. Systems thinking. Team projects.

AER E 160H: Aerospace Engineering Problems With Computer Applications Laboratory: Honors
(2-2) Cr. 3. F.S.
Prereq: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165
Solving aerospace engineering problems and presenting solutions through technical reports. Significant figures. SI units and estimation. Graphing and curve fitting. Introduction to aerospace engineering and engineering design. Spreadsheet programs. History of aerospace. Systems thinking. Team projects.

AER E 161: Numerical, Graphical and Laboratory Techniques for Aerospace Engineering
(2-2) Cr. 3. F.S.
Prereq: Credit or enrollment in AER E 160 or equivalent course
Computer-based problem solving using Matlab(R), with emphasis on numerical methods. Introduction to solid modeling and aerospace design using SolidWorks.

AER E 161H: Numerical, Graphical and Laboratory Techniques for Aerospace Engineering: Honors
(2-2) Cr. 3. F.S.
Prereq: AER E 160 or equivalent course
Computer-based problem solving using Matlab(R), with emphasis on numerical methods. Introduction to solid modeling and aerospace design using SolidWorks.

AER E 192: Aerospace Seminar
Cr. R. S.
Vectors, differentiation, integration, matrices, and systems of linear equations.

AER E 192H: Aerospace Seminar: Honors.
Cr. R. S.
Vectors, differentiation, integration, matrices, and systems of linear equations.

AER E 261: Introduction to Performance and Design
(3-0) Cr. 3. F.S.
Prereq: MATH 166, PHYS 221, credit or enrollment in AER E 161
Aerodynamics of the airplane, lift and drag, drag polar, propulsion characteristics of turbojets and piston props, level flight, range, endurance, climbing flight, turning flight, take-off and landing, design examples.

AER E 265: Scientific Balloon Engineering and Operations
(Cross-listed with MTEOR). (0-2) Cr. 1. Repeatable. F.
Engineering aspects of scientific balloon flights. Integration of science mission objectives with engineering requirements. Operations team certification. FAA and FCC regulations, communications, and command systems. Flight path prediction and control.

AER E 290: Aerospace Engineering Independent Study: Independent Study
Cr. 1-2. Repeatable.
Prereq: Sophomore classification, approval of the department

AER E 290A: Aerospace Engineering Independent Study: Flight ground instruction
Cr. 1-2. Repeatable.
Prereq: Sophomore classification, approval of the department

AER E 290B: Aerospace Engineering Independent Study: In-flight training
Cr. 1-2. Repeatable.
Prereq: AER E 301

AER E 290C: Aerospace Engineering Independent Study: Other
Cr. 1-2. Repeatable.
Prereq: AER E 301

AER E 294: Make to Innovate I
Cr. 1. Repeatable, maximum of 3 credits. F.S.
Prereq: Restricted to Freshman and Sophomore classifications, Instructor permission required.
Multidisciplinary projects to engage students in the fundamentals of engineering, project management, systems engineering, teamwork, and oral and visual communication. Students will define and attain their team objectives and milestones that are approved by the instructor. Can only be used toward graduation in these cases. To make credit deficiencies in 100 or 200 level courses. No more than 2 credits of Aer E 294X can be used to make-up credit deficiencies in 100 or 200 level courses. Cannot be used in any category or technical electives in the Aer E curriculum

AER E 301: Flight Experience
Cr. R. F.S.
Prereq: Credit or enrollment in AER E 355
Two hours of in-flight training and necessary ground instruction. Course content prescribed by the Aerospace Engineering Department. Ten hours of flight training certified in a pilot log book can be considered by the course instructor as evidence of satisfactory performance in the course. Offered on a satisfactory-fail basis only.

AER E 310: Aerodynamics I: Incompressible Flow
(3-0) Cr. 3. F.S.
Prereq: Grade of C- or better in AER E 261 and MATH 265
Introduction to fluid mechanics and aerodynamics. Fluid properties and kinematics. Conservation equations in differential and integral form. Bernoulli's equation. Basic potential flow concepts and solutions. Boundary layer concept. Incompressible flow over airfoils and wings. Examples of numerical methods. Applications of multi-variable calculus to fluid mechanics and aerodynamics.

AER E 311: Aerodynamics II: Compressible Flow
(3-0) Cr. 3. F.S.
Prereq: AER E 310, M E 231
Review of thermodynamics, energy equation, compressible flow, and isentropic flow. Normal and oblique shocks. Mach waves and expansion fans. Applications to ducts and nozzles. Compressible airfoil and wing theory. Introduction to advanced compressible flow topics.

AER E 321: Flight Structures Analysis
(3-0) Cr. 3. F.S.
Prereq: E M 324, Credit or enrollment in MATH 266 or 267
Introduction to elasticity, airworthiness, and flight loads. Introduction to fatigue. Materials selection for flight applications. Thin walled cross-sections under bending, torsion, and shear loads using classical methods. Shear center. Column buckling. Matrix methods of structural analysis.

AER E 322: Aerospace Structures Laboratory
(1-2) Cr. 2. F.S.
Prereq: Credit or enrollment in AER E 321
Design of experiments. Data analysis. Strain gage installation. Measurement of stiffness/strength of aluminum. Analysis/fabrication/testing of riveted joints. Shear/bending measurements inbeam sections. Analysis/measurement of strains in frames. Buckling of columns. Stress concentration. Vibration testing of beams and plates. Fabrication/testing of composites.

AER E 331: Flight Control Systems I
(3-0) Cr. 3. F.S.
Prereq: AER E 355
Linear system analysis. Control system designs using root-locus and frequency response methods. Applications in flight control systems.

AER E 344: Aerodynamics and Propulsion Laboratory
(2-2) Cr. 3. F.S.
Prereq: AER E 310; Coreq: AER E 311
Similitude and dimensional analysis. Measurement uncertainty analysis. Pressure and velocity measurement methods and instruments. Pressure distribution around a circular cylinder. Aerodynamic performance of low-speed airfoils. Airfoil wake flow; Boundary layer flow. Flow visualization techniques for supersonic flows and de Laval nozzles.

AER E 351: Astrodynamics I
(3-0) Cr. 3. F.S.
Prereq: M E 345
Introduction to astrodynamics. Two-body Keplerian satellite and planetary motion. Geocentric and extraterrestrial trajectories and applications. Ballistic missiles.

AER E 355: Aircraft Flight Dynamics and Control
(3-0) Cr. 3. F.S.
Prereq: AER E 261, MATH 267, M E 345
Aircraft rigid body equations of motion, linearization, and modal analysis. Longitudinal and lateral-directional static and dynamic stability analysis. Flight handling characteristics analysis. Longitudinal and lateral-directional open loop response to aircraft control inputs. Aircraft flight handling qualities.

AER E 361: Computational Techniques for Aerospace Design
(2-2) Cr. 3. F.S.
Prereq: AER E 310, MATH 267, E M 324, M E 345
Advanced programming, workstation environment, and development of computational tools for aerospace analysis and design. Technical report writing.

AER E 362: Aerospace Systems Integration
(3-0) Cr. 3. F.S.
Prereq: ENGL 250, Junior standing in Aerospace Engineering or permission of instructor
Emphasis on impact of component interfaces in aerospace systems. Understand how changes in variables associated with individual components impact the performance of the aerospace system. Solving aerospace engineering problems and presenting solutions through reports. Specific integration challenges include: capturing implicit disciplinary interactions (e.g. structures/aerodynamics, propulsion/aerodynamics, etc.), propagating tolerances through the system (i.e. uncertainty modeling), balancing component attributes in the system objective.

AER E 381: Introduction to Wind Energy
(3-0) Cr. 3. S.
Prereq: MATH 166, PHYS 221
Basic introduction to the fundamentals of Wind Energy and Wind Energy conversion systems. Topics include but not limited to various types of wind energy conversion systems and the aerodynamics, blade and tower structural loads, kinematics of the blades and meteorology.

AER E 396: Summer Internship
Cr. R. Repeatable. SS.
Prereq: Permission of department and Engineering Career Services
Professional work period of at least 10 weeks during the summer. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

AER E 398: Cooperative Education
Cr. R. Repeatable. F.S.
Prereq: Permission of department and Engineering Career Services.
Professional work period. One semester per academic or calendar year. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

AER E 407: Applied Formal Methods
(Dual-listed with AER E 507). (Cross-listed with COM S). Cr. 3. S.
Prereq: AER E 361 for AER E majors. COM S 311 for COM S majors. AER E 361 or COM S 311, or an equivalent course, plus instructor permission for other majors.
Introduction to the fundamentals of formal methods, a set of mathematically rigorous techniques for the formal specification, validation, and verification of safety- and security-critical systems. Tools, techniques, and applications of formal methods with an emphasis on real-world use-cases such as enabling autonomous operation. Build experience in writing mathematically analyzable specifications from English operational concepts for real cyberphysical systems, such as aircraft and spacecraft. Review capabilities and limitations of formal methods in the design, verification, and system health management of today's complex systems.

AER E 411: Aerospace Vehicle Propulsion
(3-0) Cr. 3. F.S.
Prereq: AER E 311, AER E 344
Atmospheric propulsion system performance and cycle analysis. Momentum theorem, thrust and propulsive efficiency. Thermodynamics of compressible flow with heat and work addition. Components and principles of turbojet, ramjet, and turbofan aircraft engines. Introduction to rocket engines.

AER E 412: Spacecraft Electric Propulsion
(3-0) Cr. 3. S.
Prereq: AER E 311
Electricity and magnetism. Plasma physics. Ion engine performance. Introduction to advanced electromagnetic propulsion systems. Energy sources and nuclear propulsion. Space mission requirements.

AER E 415: Rocket Propulsion
(3-0) Cr. 3. F.S.
Prereq: AER E 311 and AER E 344
Components and principles of liquid rocket engines, solid rocket motors, and hybrid rocket motors. Rocket flight performance and rocket staging. Combustion and thermochemistry. Rocket cooling and nozzle heat transfer. Introduction to nuclear thermal propulsion and electric propulsion systems. Applications to spacecraft.

AER E 417: Experimental Mechanics
(Dual-listed with AER E 517). (Cross-listed with E M). (2-2) Cr. 3. Alt. F., offered even-numbered years.
Prereq: E M 324; MAT E 273
Introduction to fundamental concepts for force, displacement, stress and strain measurements for structures and materials applications. Strain gage theory and application. Full field deformation measurements with laser interferometry and digital image processing. Advanced experimental concepts at the micro- and nano-scale regimes. Selected laboratory experiments.

AER E 421: Advanced Flight Structures
(2-2) Cr. 3. F.S.
Prereq: AER E 321, MATH 266 or MATH 267
Analysis of indeterminate flight structures including finite element laboratory. Static analysis of complex structural components subject to thermal and aerodynamic loads. Analytical and finite element solutions for stresses and displacements of membrane, plane stress, plate structures. Buckling of beams, frames, and plate structures. Introduction to vibration of flight structures. Steady state and transient structural response using normal modal analysis.

AER E 422: Vibrations and Aeroelasticity
(3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: E M 324 or AER E 321
Vibration theory. Steady and unsteady flows. Mathematical foundations of aeroelasticity, static and dynamic aeroelasticity. Linear unsteady aerodynamics, non-steady aerodynamics of lifting surfaces. Stall flutter. Aeroelastic problems in civil engineering structures. Aeroelastic problems of rotorcraft. Experimental aeroelasticity. Selected wind tunnel laboratory experiments.

AER E 423: Composite Flight Structures
(2-2) Cr. 3. S.
Prereq: E M 324; MAT E 273
Fabrication, testing and analysis of composite materials used in flight structures. Basic laminate theory of beams, plates and shells. Manufacturing and machining considerations of various types of composites. Testing of composites for material properties, strength and defects. Student projects required.

AER E 426: Design of Aerospace Structures
(Dual-listed with AER E 526). (2-2) Cr. 3. F.
Prereq: E M 324
Detailed design and analysis of aerospace vehicle structures. Material selection, strength, durability and damage tolerance, and validation analysis. Design for manufacturability.

AER E 432: Flight Control Systems II
(3-0) Cr. 3. F.
Prereq: AER E 331
Aircraft lateral directional stability augmentation. Launch vehicle pitch control system design. Control of flexible vehicles. Satellite attitude control. Flight control designs based on state-space methods. Introduction to sample-data systems.

AER E 433: Spacecraft Dynamics and Control
(3-0) Cr. 3. F.
Prereq: M E 345
Three-dimensional rotational kinematics and attitude dynamics of a rigid body in space. Classical stability analysis of spinning spacecraft with or without energy dissipation. Attitude dynamics, stability, and control of spacecraft in a circular orbit in the presence of gravity-gradient torques. Introduction to spacecraft attitude determination and control systems (ADCS) with emphasis on modern attitude determination algorithms. Simulation of spacecraft attitude dynamics and control problems of practical interest using programming and analysis software.

AER E 442: V/STOL Aerodynamics and Performance
(3-0) Cr. 3. F.
Prereq: AER E 261
Introduction to the aerodynamics, performance, stability, control and critical maneuvering characteristics of V/STOL vehicles. Topics include hovercrafts, jet flaps, ducted fans and thrust vectored engines.

AER E 445: Experimental Flow Mechanics and Heat Transfer
(Dual-listed with AER E 545). (3-0) Cr. 3. F.
Prereq: AER E 310 or M E 335 or A B E 378
Similitude and dimensional analysis. Measurement uncertainty analysis; Fluid mechanical apparatus: wind tunnel and water tunnels. Various experimental techniques widely used for fluid mechanics, aerodynamics, heat transfer, and combustion studies: Pressure gauge and transducers; Pitot tube; hot wire anemometry; Shadowgraph and Schlieren Photography; laser Doppler velocimetry; particle image velocimetry (PIV); advanced PIV techniques (stereo PIV, 3-D PIV, Tomographic PIV, Holograph PIV and microscopic PIV); laser induced fluorescence; pressure sensitive painting, temperature sensitive painting; molecular tagging velocimetry; molecular tagging thermometry. Extensive applications and laboratory experiments will be included.

AER E 446: Computational Fluid Dynamics
(3-0) Cr. 3. F.
Prereq: AER E 311, AER E 361 and proficiency in at least one programming language
Introduction to computational fluid dynamics. Discretization, consistency, and stability. Explicit and implicit methods for ordinary and partial differential equations. Linearization techniques. Iterative and direct solution algorithms. Numerical methods for parabolic, elliptic and hyperbolic equations. Curvilinear coordinates and numerical grid generation. Applications to Euler, boundary-layer and Navier-Stokes equations.

AER E 448: Fluid Dynamics of Turbomachinery
(Cross-listed with M E). (3-0) Cr. 3. S.
Prereq: AER E 311 or M E 335
Applications of principles of fluid mechanics and thermodynamics in performance analysis and design of turbomachines. Conceptual and preliminary design of axial and radial flow compressors and turbines using velocity triangles and through-flow approaches.

AER E 451: Astrodynamics II
(3-0) Cr. 3. F.S.
Prereq: AER E 351
Orbit determination and prediction using Gibb's and Gauss' methods. Advanced orbit maneuvers, triple-, and fixed-impulse; universal variables; Kepler's problem. Earth gravity field models and gravity harmonics, orbit perturbations, advanced dynamics, variational methods, relative orbital mechanics, and Clohessy-Wiltshire equations.

AER E 452: Introduction To Systems Engineering And Analysis
(Cross-listed with I E). Cr. 3. SS.
Prereq: Junior Classification in an Engineering Major
Principles of systems engineering to include problem statement formulation, stakeholder analysis, requirements definition, system architecture and concept generation, system integration and interface management, verification and validation, and system commissioning and decommissioning operations. Introduction to discrete event simulation processes. Students will work in groups to propose, research, and present findings for a systems engineering topic of current relevance.

AER E 461: Modern Design Methodology with Aerospace Applications
(2-2) Cr. 3. F.S.
Prereq: AER E 361, AER E 311, AER E 321, AER E 322, AER E 344, AER E 351, AER E 355
Introduction to modern engineering design methodology. Computational constrained optimal design approach including selection of objective function, characterization of constraint system, materials and strength considerations, and sensitivity analyses. The class contains two focus sections. One section assigns design projects in Aeronautics, and the other assigns design projects in Astronautics.

AER E 462: Design of Aerospace Systems
(1-4) Cr. 3. F.S.
Prereq: AER E 461
Fundamental principles used in engineering design of aircraft, rockets, and space systems. Preliminary design of aerospace vehicles. Engineering Ethics. The class contains two focus sections. One section assigns design projects in Aeronautics, and the other section assigns design projects in Astronautics.

AER E 463: Introduction to Multidisciplinary Design Optimization
(Dual-listed with AER E 563). (3-0) Cr. 3. F.
Prereq: senior standing in College of Engineering or permission of instructor
Introduction to the theory and methods of Multidisciplinary Design Optimization (MDO), including system coupling, system sensitivity methods, decomposition methods, MDO formulations (such as multi-discipline feasible (MDF), individual discipline feasible (IDF) and all-at-once (AAO) approaches, and MDO search methods.

AER E 464: Spacecraft Systems
(3-0) Cr. 3. S.
Prereq: AER E 351
An examination of spacecraft systems including attitude determination and control, power, thermal control, communications, propulsion, guidance, navigation, command and data handling, and mechanisms. Explanation of space and operational environments as they impact spacecraft design. Includes discussion of safety, reliability, quality, maintainability, testing, cost, legal, and logistics issues.

AER E 466: Multidisciplinary Engineering Design
(Cross-listed with A B E, B M E, CPR E, E E, ENGR, I E, M E, MAT E). (1-4) Cr. 3. Repeatable. F.S.
Prereq: Student must be within two semesters of graduation; permission of instructor.
Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

AER E 467: Multidisciplinary Engineering Design II
(Cross-listed with ENGR, I E, M E, MAT E). (1-4) Cr. 3. Repeatable, maximum of 2 times. Alt. F., offered irregularly.Alt. S., offered irregularly.
Prereq: Student must be within two semesters of graduation or receive permission of instructor.
Build and test of a conceptual design. Detail design, manufacturability, test criteria and procedures. Application of design tools such as CAD and CAM and manufacturing techniques such as rapid prototyping. Development and testing of a full-scale prototype with appropriate documentation in the form of design journals, written reports, oral presentations and computer models and engineering drawings.

AER E 468: Large-Scale Complex Engineered Systems (LSCES)
(Dual-listed with AER E 568). (Cross-listed with I E). (3-0) Cr. 3. S.
Prereq: senior standing in College of Engineering or permission of AerE 468 instructor
Introduction to the theoretical foundation and methods associated with the design for large-scale complex engineered systems, including objective function formation, design reliability, value-driven design, product robustness, utility theory, economic factors for the formation of a value function and complexity science as a means of detecting unintended consequences in the product behavior.

AER E 480: Ultrasonic Nondestructive Evaluation
(Cross-listed with E M). (3-0) Cr. 3. S.
Prereq: E M 324, MATH 266 or MATH 267, PHYS 232
Introduction to stress/strain, Hooke's law, and elastic wave propagation in two dimensions in isotropic media. Ultrasonic plane-wave reflection and transmission; and simple straight-crested guided waves. Transducer construction, behavior, and performance. Simple signal analysis and discrete signal processing. The last few weeks of the course are devoted to case studies.

AER E 481: Advanced Wind Energy: Technology and Design
(3-0) Cr. 3. S.
Prereq: AER E 381 or senior classification in engineering or junior in engineering with a course in fluid mechanics
Advanced topics in wind energy, emphasis on current practices. Theoretical foundations for horizontal and vertical axis wind turbine. Design codes for energy conversion systems design, aerodynamic and structural load estimation, wind resource characterization wind farm design, optimization.

AER E 483: Aeroacoustics
(Dual-listed with AER E 583). Cr. 3.
Prereq: AER E 311 or M E 335; and MATH 266 or MATH 267
Noise metrics, Linear wave equation and its solution in 1-, 2-, and 3-D using Green's functions. Propagation of sound in free and confined spaces. Aerodynamic noise sources in engineering machines: aircraft engine noise, airfram noise, wind turbine noise, etc.

AER E 490: Aerospace Engineering Independent Study
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490A: Aerospace Engineering Independent Study: Aero and/or Gas Dynamics
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490B: Aerospace Engineering Independent Study: Propulsion
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490C: Aerospace Engineering Independent Study: Aerospace Structures
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490D: Aerospace Engineering Independent Study: Flight Dynamics
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490E: Aerospace Engineering Independent Study: Spacecraft Systems
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490F: Aerospace Engineering Independent Study: Flight Control Systems
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490G: Aerospace Engineering Independent Study: Aeroelasticity
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490H: Aerospace Engineering Independent Study: Independent Study, Honors
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490I: Aerospace Engineering Independent Study: Design
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490J: Aerospace Engineering Independent Study: Non-destructive Evaluation
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490K: Aerospace Engineering Independent Study: Wind Engineering
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490L: Aerospace Engineering Independent Study: Multi-functional Ultra-light Structures
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 490M: Aerospace Engineering Independent Study: Intelligent Systems and Autonomy
Cr. 1-6. Repeatable. F.S.SS.
Prereq: Junior or senior classification, approval of department

AER E 490O: Aerospace Engineering Independent Study: Other
Cr. 1-6. Repeatable.
Prereq: Junior or senior classification, approval of the department

AER E 494: Make to Innovate II
Cr. 2-3. Repeatable, maximum of 3 times. F.S.
Prereq: Restricted to Junior or Senior classifications, Instructor permission required.
Multidisciplinary projects to engage students in the fundamentals of engineering, project management, systems engineering, teamwork, and oral and visual communication. Students will define and attain their team objectives and milestones that are approved by their instructors. Maximum of 6 credits may count toward graduation as Technical Elective.

AER E 499: Senior Project
Cr. 1-2. Repeatable. F.S.
Prereq: Senior classification, credit or enrollment in AER E 491
Development of aerospace principles and concepts through individual research and projects. Written report.

Courses primarily for graduate students, open to qualified undergraduates:

AER E 501: Advanced Engineering Analysis
(3-0) Cr. 3. F.
Prereq: Math 267 or equivalent
Linear ordinary differential equations with variable coefficients; hyperbolic, parabolic, and elliptic equations; tensors. None

AER E 507: Applied Formal Methods
(Dual-listed with AER E 407). (Cross-listed with COM S). Cr. 3. S.
Prereq: AER E 361 for AER E majors. COM S 311 for COM S majors. AER E 361 or COM S 311, or an equivalent course, plus instructor permission for other majors.
Introduction to the fundamentals of formal methods, a set of mathematically rigorous techniques for the formal specification, validation, and verification of safety- and security-critical systems. Tools, techniques, and applications of formal methods with an emphasis on real-world use-cases such as enabling autonomous operation. Build experience in writing mathematically analyzable specifications from English operational concepts for real cyberphysical systems, such as aircraft and spacecraft. Review capabilities and limitations of formal methods in the design, verification, and system health management of today's complex systems.

AER E 511: Wind Energy System Design
(Cross-listed with WESEP). (3-0) Cr. 3.
Prereq: WESEP 501 and WESEP 502
Advanced design, control, and operation of wind plants. Topics include electromechanical energy conversion systems, aerodynamic and aeroelastic loads, optimal control of wind farms, life cycle management strategies, tall tower design, and prediction of component residual life.

AER E 514: Advanced Mechanics of Materials
(Cross-listed with E M). (3-0) Cr. 3. F.
Prereq: E M 324
Theory of stress and strain, stress-strain relationships. Unsymmetrical bending, curved beams, shear center. Torsion of thin-walled noncircular sections. Equilibrium, compatibility equations. Airy stress functions. Membrane stresses in shells, thick-walled cylinders.

AER E 517: Experimental Mechanics
(Dual-listed with AER E 417). (Cross-listed with E M). (2-2) Cr. 3. Alt. F., offered even-numbered years.
Prereq: E M 324; MAT E 273
Introduction to fundamental concepts for force, displacement, stress and strain measurements for structures and materials applications. Strain gage theory and application. Full field deformation measurements with laser interferometry and digital image processing. Advanced experimental concepts at the micro- and nano-scale regimes. Selected laboratory experiments.

AER E 521: Airframe Analysis
(3-0) Cr. 3. F.
Prereq: AER E 421 or E M 424
Analysis of static stresses and deformation in continuous aircraft structures. Various analytical and approximate methods of analysis of isotropic and anisotropic plates and shells.

AER E 522: Design and Analysis of Composite Materials
(3-0) Cr. 3. F.
Prereq: E M 324
Composite constituent materials, micro-mechanics, laminate analysis, hygro-thermal analysis, composite failure, joining of composites, design of composite beams and plates, honeycomb core, manufacturing of composites, short fiber composites, and demonstration laboratory.

AER E 524: Numerical Mesh Generation
(3-0) Cr. 3. F.
Prereq: MATH 385, proficiency in programming
Introduction to modern mesh generation techniques. Structured and unstructured mesh methods, algebraic and PDE methods, elliptic and hyperbolic methods, variational methods, error analysis, Delaunay triangulation, data structures, geometric modeling with B-spline and NURBS surfaces, surface meshing.

AER E 525: Finite Element Analysis
(Cross-listed with E M). (3-0) Cr. 3. S.
Prereq: E M 425, MATH 385
Variational and weighted residual approach to finite element equations. Emphasis on two- and three-dimensional problems in solid mechanics. Isoparametric element formulation, higher order elements, numerical integration, imposition of constraints and penalty, convergence, and other more advanced topics. Use of two- and three-dimensional computer programs. Dynamic and vibrational problems, eigenvalues, and time integration. Introduction to geometric and material nonlinearities.

AER E 526: Design of Aerospace Structures
(Dual-listed with AER E 426). (2-2) Cr. 3. F.
Prereq: E M 324
Detailed design and analysis of aerospace vehicle structures. Material selection, strength, durability and damage tolerance, and validation analysis. Design for manufacturability.

AER E 531: Automatic Control of Flight Vehicles
(3-0) Cr. 3. S.
Prereq: AER E 331
Applications of classical and modern linear control theory to automatic control of flight vehicles. Spacecraft attitude control. Control of flexible vehicles. Linear-quadratic regulator design applications.

AER E 532: Compressible Fluid Flow
(Cross-listed with M E). (3-0) Cr. 3. S.
Prereq: AER E 310, 311 or equivalent
Thermodynamics of compressible flow. Viscous and inviscid compressible flow equations. One dimensional steady flow; isentropic flow, shocks, expansions. Multidimensional compressible flow aspects. Linear and nonlinear wave analysis and method of characteristics. Subsonic, transonic, supersonic and hypersonic flows.

AER E 541: Incompressible Flow Aerodynamics
(3-0) Cr. 3. F.
Prereq: AER E 310 or M E 335 or equivalent
Kinematics and dynamics of fluid flow. Derivation of the Navier-Stokes, Euler and potential flow equations. Introduction to generalized curvilinear coordinates. Ideal fluids. Two-dimensional and three-dimensional potential flow. Complex variable methods.

AER E 545: Experimental Flow Mechanics and Heat Transfer
(Dual-listed with AER E 445). (3-0) Cr. 3. F.
Prereq: AER E 310 or M E 335 or A B E 378
Similitude and dimensional analysis. Measurement uncertainty analysis; Fluid mechanical apparatus: wind tunnel and water tunnels. Various experimental techniques widely used for fluid mechanics, aerodynamics, heat transfer, and combustion studies: Pressure gauge and transducers; Pitot tube; hot wire anemometry; Shadowgraph and Schlieren Photography; laser Doppler velocimetry; particle image velocimetry (PIV); advanced PIV techniques (stereo PIV, 3-D PIV, Tomographic PIV, Holograph PIV and microscopic PIV); laser induced fluorescence; pressure sensitive painting, temperature sensitive painting; molecular tagging velocimetry; molecular tagging thermometry. Extensive applications and laboratory experiments will be included.

AER E 546: Computational Fluid Mechanics and Heat Transfer I
(Cross-listed with M E). (3-0) Cr. 3. F.
Prereq: AER E 310 or M E 335, and programming experience
Basic concepts of discretization, consistency, and stability. Explicit and implicit methods for ordinary differential equations. Methods for each type of partial differential equation. Iterative solution methods; curvilinear grids. Students will program basic algorithms.

AER E 547: Computational Fluid Mechanics and Heat Transfer II
(Cross-listed with M E). (3-0) Cr. 3. S.
Prereq: AER E 546 or equivalent
Application of computational methods to current problems in fluid mechanics and heat transfer. Methods for solving the Navier-Stokes and reduced equation sets such as the Euler, boundary layer, and parabolized forms of the conservation equations. Introduction to relevant aspects of grid generation and turbulence modeling.

AER E 551: Orbital Mechanics
(3-0) Cr. 3. F.
Prereq: AER E 351
Review of 2-body problem. Orbital maneuvers. Relative motion in orbit. Orbit perturbation analysis. Gravity field expansions and effects on orbiters. 3-body problem with applications.

AER E 556: Guidance and Navigation of Aerospace Vehicles
(3-0) Cr. 3. F.
Prereq: AER E 331
Principles of guidance systems for spacecraft, launch vehicles, homing and ballistic missiles. Optimal guidance. Interplanetary transfer guidance with low thrust. Principles of inertial navigation. Theory and applications of the Global Positioning System. Celestial navigation procedures. Application of Kalman filtering to recursive navigation theory.

AER E 563: Introduction to Multidisciplinary Design Optimization
(Dual-listed with AER E 463). (3-0) Cr. 3. F.
Prereq: senior standing in College of Engineering or permission of instructor
Introduction to the theory and methods of Multidisciplinary Design Optimization (MDO), including system coupling, system sensitivity methods, decomposition methods, MDO formulations (such as multi-discipline feasible (MDF), individual discipline feasible (IDF) and all-at-once (AAO) approaches, and MDO search methods.

AER E 564: Fracture and Fatigue
(Cross-listed with E M, M E, M S E). (3-0) Cr. 3. Alt. F., offered even-numbered years.
Prereq: E M 324 and either MAT E 216 or MAT E 273 or MAT E 392. Undergraduates: Permission of instructor
Materials and mechanics approach to fracture and fatigue. Fracture mechanics, brittle and ductile fracture, fracture and fatigue characteristics, fracture of thin films and layered structures. Fracture and fatigue tests, mechanics and materials designed to avoid fracture or fatigue.

AER E 565: Systems Engineering and Analysis
(Cross-listed with E E, I E). (3-0) Cr. 3.
Prereq: Coursework in basic statistics
Introduction to organized multidisciplinary approach to designing and developing systems. Concepts, principles, and practice of systems engineering as applied to large integrated systems. Life-cycle costing, scheduling, risk management, functional analysis, conceptual and detail design, test evaluation, and systems engineering planning and organization. Not available for degrees in industrial engineering

AER E 566: Avionics Systems Engineering
(Cross-listed with E E). (3-0) Cr. 3. S.
Prereq: E E 565
Avionics functions. Applications of systems engineering principles to avionics. Top-down design of avionics systems. Automated design tools.

AER E 568: Large-Scale Complex Engineered Systems (LSCES)
(Dual-listed with AER E 468). (Cross-listed with I E). (3-0) Cr. 3. S.
Prereq: senior standing in College of Engineering or permission of AerE 468 instructor
Introduction to the theoretical foundation and methods associated with the design for large-scale complex engineered systems, including objective function formation, design reliability, value-driven design, product robustness, utility theory, economic factors for the formation of a value function and complexity science as a means of detecting unintended consequences in the product behavior.

AER E 569: Mechanics of Composite and Combined Materials
(Cross-listed with E M, M S E). (3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: E M 324
Mechanics of fiber-reinforced materials. Micromechanics of lamina. Macromechanical behavior of lamina and laminates. Strength and interlaminar stresses of laminates. Failure criteria. Stress analysis of laminates. Thermal moisture and residual stresses. Joints in composites.

AER E 570: Wind Engineering
(Cross-listed with E M). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 378, M E 345
Atmospheric circulations, atmospheric boundary layer wind, bluff-body aerodynamics, aeroelastic phenomena, wind-tunnel and full-scale testing, wind-load code and standards, effect of tornado and thunderstorm winds, design applications.

AER E 572: Turbulence
(Cross-listed with CH E). (3-0) Cr. 3.
Prereq: AER E 541 or M E 538
Qualitative features of turbulence. Statistical representation of turbulent velocity fields: averages, moments, correlations, length and time scales and the energy cascade. Averaged equations of motion, closure requirements, Reynolds averaged models. Homogeneous shear flows, free shear flows, boundary layers. Numerical simulation of turbulence: DNS, LES, DES.

AER E 573: Random Signal Analysis and Kalman Filtering
(Cross-listed with E E, M E). (3-0) Cr. 3. F.
Prereq: E E 324 or AER E 331 or M E 370 or M E 411 or MATH 341
Elementary notions of probability. Random processes. Autocorrelation and spectral functions. Estimation of spectrum from finite data. Response of linear systems to random inputs. Discrete and continuous Kalman filter theory and applications. Smoothing and prediction. Linearization of nonlinear dynamics.

AER E 574: Optimal Control
(Cross-listed with E E, M E). (3-0) Cr. 3. S.
Prereq: E E 577
The optimal control problem. Variational approach. Pontryagin's principle, Hamilton-Jacobi equation. Dynamic programming. Time-optimal, minimum fuel, minimum energy control systems. The regulator problem. Structures and properties of optimal controls.

AER E 575: Introduction to Robust Control
(Cross-listed with E E, M E). (3-0) Cr. 3.
Prereq: E E 577
Introduction to modern robust control. Model and signal uncertainty in control systems. Uncertainty description. Stability and performance robustness to uncertainty. Solutions to the H2, Hoo, and l1 control problems. Tools for robustness analysis and synthesis.

AER E 576: Digital Feedback Control Systems
(Cross-listed with E E, M E). (3-0) Cr. 3. F.
Prereq: E E 475 or AER E 432 or M E 411 or MATH 415; and MATH 267
Sampled data, discrete data, and the z-transform. Design of digital control systems using transform methods: root locus, frequency response and direct design methods. Design using state-space methods. Controllability, observability, pole placement, state estimators. Digital filters in control systems. Microcomputer implementation of digital filters. Finite wordlength effects. Linear quadratic optimal control in digital control systems. Simulation of digital control systems.

AER E 577: Linear Systems
(Cross-listed with E E, M E, MATH). (3-0) Cr. 3. F.
Prereq: E E 324 or AER E 331 or MATH 415; and MATH 207
Linear algebra review. Least square method and singular value decomposition. State space modeling of linear continuous-time systems. Solution of linear systems. Controllability and observability. Canonical description of linear equations. Stability of linear systems. State feedback and pole placements. Observer design for linear systems.

AER E 578: Nonlinear Systems
(Cross-listed with E E, M E, MATH). (3-0) Cr. 3. S.
Prereq: E E 577
Linear vs nonlinear systems. Phase plane analysis. Bifurcation and center manifold theory. Lyapunov stability. Absolute stability of feedback systems. Input-output stability. Passivity theory and feedback linearization. Nonlinear control design techniques.

AER E 581: Perturbation Methods
(3-0) Cr. 3. F.
Prereq: MATH 267
Mathematical perturbation methods with applications to ordinary and partial differential equations. Perturbation expansions. Order of magnitude and gauge functions. Matched asymptotic expansions. Boundary layer problems. Multiple scales. Resonance and mode coupling. Solvability conditions for differential equations. Physical and engineering applications.

AER E 583: Aeroacoustics
(Dual-listed with AER E 483). Cr. 3.
Prereq: AER E 311 or M E 335; and MATH 266 or MATH 267
Noise metrics, Linear wave equation and its solution in 1-, 2-, and 3-D using Green's functions. Propagation of sound in free and confined spaces. Aerodynamic noise sources in engineering machines: aircraft engine noise, airfram noise, wind turbine noise, etc.

AER E 590: Aerospace Engineering Independent Study: Special Topics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590A: Aerospace Engineering Independent Study: Aero and/or Gas Dynamics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590B: Aerospace Engineering Independent Study: Propulsion
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590C: Aerospace Engineering Independent Study: Aerospace Structures
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590D: Aerospace Engineering Independent Study: Flight Dynamics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590E: Aerospace Engineering Independent Study: Spacecraft Systems
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590F: Aerospace Engineering Independent Study: Flight Control Systems
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590G: Aerospace Engineering Independent Study: Aeroelasticity
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590H: Aerospace Engineering Independent Study: Viscous Aerodynamics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590I: Aerospace Engineering Independent Study: Design
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590J: Aerospace Engineering Independent Study: Hypersonics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590K: Aerospace Engineering Independent Study: Computational Aerodynamics
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590L: Aerospace Engineering Independent Study: Optimization
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590M: Aerospace Engineering Independent Study: Non Destructive Evaluation
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 590N: Aerospace Engineering Independent Study: Wind Engineering
Cr. 1-5. Repeatable, maximum of 3 times.

AER E 591: Graduate Student Seminar Series
Cr. R. Repeatable.
Presentation of professional topics by department graduate students. Development of presentation skills used in a professional conference setting involving question and answer format.

AER E 599: Creative Component
Cr. 1-5. Repeatable.

Courses for graduate students:

AER E 640: Stability of Fluid Flow
(3-0) Cr. 3.
Prereq: AerE 541
Theoretical methods of stability analysis; linear analysis of exchange of stability and over stability; bifurcation of equilibria; most dangerous modes and pattern formation; shear flow stability theorems. Physical mechanisms. Tollmein-Schlichting waves, disintegration of capillary jets, Benard convection, Taylor-Couette flow, centrifugal instability, double diffusion.

AER E 647: Advanced Computational Fluid Dynamics
(Cross-listed with M E). (3-0) Cr. 3. S.
Prereq: AER E 547
An examination of current methods in computational fluid dynamics. Differencing strategies. Advanced solution algorithms for unstructured meshes. Grid generation. Construction of higher-order CFD algorithms. Parallel computing. Current applications. Use of state of the art CFD codes.

AER E 690: Aerospace Engineering Independent Study: Advanced Topics
Cr. 1-5. Repeatable.

AER E 690A: Aerospace Engineering Independent Study: Aero and/or Gas Dynamics
Cr. 1-5. Repeatable.

AER E 690B: Aerospace Engineering Independent Study: Propulsion
Cr. 1-5. Repeatable.

AER E 690C: Aerospace Engineering Independent Study: Aerospace Structures
Cr. 1-5. Repeatable.

AER E 690D: Aerospace Engineering Independent Study: Flight Dynamics
Cr. 1-5. Repeatable.

AER E 690E: Aerospace Engineering Independent Study: Spacecraft Systems
Cr. 1-5. Repeatable.

AER E 690F: Aerospace Engineering Independent Study: Flight Control Systems
Cr. 1-5. Repeatable.

AER E 690G: Aerospace Engineering Independent Study: Aeroelasticity
Cr. 1-5. Repeatable.

AER E 690H: Aerospace Engineering Independent Study: Viscous Aerodynamics
Cr. 1-5. Repeatable.

AER E 690I: Aerospace Engineering Independent Study: Design
Cr. 1-5. Repeatable.

AER E 690J: Aerospace Engineering Independent Study: Hypersonics
Cr. 1-5. Repeatable.

AER E 690K: Aerospace Engineering Independent Study: Computational Aerodynamics
Cr. 1-5. Repeatable.

AER E 690L: Aerospace Engineering Independent Study: Non Destructive Evaluation
Cr. 1-5. Repeatable.

AER E 690M: Aerospace Engineering Independent Study: Wind Engineering
Cr. 1-5. Repeatable.

AER E 697: Engineering Internship
Cr. R. Repeatable.
Prereq: Permission of DOGE (Director of Graduate Education), graduate classification
One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

AER E 699: Research
Cr. arr. Repeatable.