Aerospace Engineering

Undergraduate Study

For undergraduate curriculum in aerospace engineering leading to the degree bachelor of science. This curriculum 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, water, 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:

Within three to five years after graduation, Aerospace Engineering alumni will have become actively contributing, valued engineers showing professional growth or be actively pursuing an advanced degree in graduate school. They will have achieved this by:

- Utilizing their strong foundation in science, mathematics and engineering.
- Demonstrating teamwork, leadership, and integrity.
- Being aware of the societal, economic and environmental impact of their work.
- Demonstrating critical thinking and effective communication skills.
- Ensuring superior quality, customer satisfaction, and safety outcomes in their work.

Nondestructive Evaluation (NDE)

The NDE minor 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. 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.

The master of science degree requires a thesis and a minimum of 8 research credits. It has strong research emphasis and is recommended for students who anticipate entering a doctoral program later. At least 30 credits of acceptable graduate work are required for the degree.

The master of engineering degree does not require either research credits or a thesis. However, at least two credits of acceptable creative component and at least 26 credits of acceptable graduate coursework are required. A minimum of 30 credits of acceptable graduate work is required for the degree.

In another option, a master of engineering degree can be completed through 30 credits of coursework only.

The department offers a combined BS-MS program that is expected to require two additional semesters beyond the completion of the BS program. The department also offers a similar, combined BS-MBA program.

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.

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.

Curriculum in Aerospace Engineering

Leading to the degree bachelor of science.

Total credits required: 128.0.

Any transfer credit courses applied to the degree program require a grade of C or better. See also Basic Program and Special Programs.

International Perspectives [1]: 3 cr.

U.S. Diversity [1]: 3 cr.

Communication Proficiency/Library requirement:

ENGL 150	Critical Thinking and Communication (minimum grade of C)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (minimum grade of C)	3
Approval by department required		
LIB 160	Information Literacy	1

General Education Electives: 15.0 cr [2]

Complete 15 cr. including a series. A series of at least two courses must be taken to fulfill this requirement.

Basic Program: 27 cr. [4]

Complete with 2.00 GPA including transfer courses:

CHEM 167	General Chemistry for Engineering Students	4
or CHEM 177	General Chemistry I	
ENGL 150	Critical Thinking and Communication *	3
ENGL 250	Written, Oral, Visual, and Electronic Composition *	3
ENGR 101	Engineering Orientation	R
or AER E 101H	Engineering Honors Orientation	
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		27

* see above for grade requirements

Math and Physical Science: 13 cr.

MATH 265	Calculus III	4
MATH 267	Elementary Differential Equations and Laplace Transforms	4
PHYS 222	Introduction to Classical Physics II	5
Total Credits		13

Aerospace Engineering Core: 48 cr. [4]

AER E 261	Introduction to Performance and Design	4
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 321L	Aerospace Structures Laboratory	2
AER E 331	Flight Control Systems I	3
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 I	3
AER E 421	Advanced Flight Structures	3
AER E 361	Computational Techniques for Aerospace Design	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		48

Other Remaining Courses: 25 cr.

E M 274	Statics of Engineering	3
E M 345	Dynamics	3
MAT E 273	Principles of Materials Science and Engineering	3
AER E 161	Numerical, Graphical and Laboratory Techniques for Aerospace Engineering	4
3 credits from the following		3
AER E 412	Aerospace Vehicle Propulsion II	
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 442	V/STOL Aerodynamics and Performance	
AER E 446	Computational Fluid Mechanics and Heat Transfer I	
AER E 448	Fluid Dynamics of Turbomachinery	
AER E 451	Astrodynamics II	
AER E 464	Spacecraft Systems	
AER E 481	Advanced Wind Energy: Technology and Design	
Technical Electives (see below) [2]		3
Career Electives (see below) [2]		6
Total Credits		25

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 291	Aerospace Advising Seminar	R
AER E 292	Aerospace Advising Seminar	R
AER E 301	Flight Experience	R
AER E 391	Aerospace Advising Seminar	R
AER E 392	Aerospace Advising Seminar	R
AER E 491	Aerospace Advising Seminar	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.
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.
4. 2.00 required including transfer courses.

See also: A 4-year plan of study grid showing course template by semester.

Courses primarily for undergraduates:

AER E 101H. Engineering Honors Orientation.
Cr. R. F. *Prereq: Membership in the Freshman Honors Program*
Introduction to the College of Engineering and the Aerospace Engineering profession. Information concerning university, college, and department policies, procedures and resources with emphasis on the Freshman Honors Program. Topics include experiential education study abroad opportunities, and department mentorships.

AER E 112. Orientation to Learning and Productive Team Membership.
(Cross-listed with NREM, CON E, FS HN, HORT). (2-0) Cr. 2. F.
Introduction to developing intentional learners and worthy team members. Learning as the foundation of human enterprise; intellectual curiosity; ethics as a personal responsibility; everyday leadership; effective team and community interactions including team learning and the effects on individuals; and growth through understanding self, demonstrating ownership of own learning, and internalizing commitment to helping others. Intentional mental processing as a means of enhancing learning. Interconnectedness of the individual, the community, and the world.

AER E 160. Aerospace Engineering Problems With Computer Applications Laboratory.
(2-2) Cr. 3. F.S. *Prereq: Satisfactory scores on mathematics placement assessments; credit or enrollment in MATH 142, 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: Satisfactory scores on mathematics placement assessments; credit or enrollment in MATH 142, 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.
(3-2) Cr. 4. F.S. *Prereq: AER E 160 or equivalent course*
Computer solutions to aerospace engineering problems using the FORTRAN language and Matlab(R), with emphasis on numerical methods. Solid modeling with emphasis on aerospace design. Analysis of basic mathematical models and engineering problem solving. Written and oral technical reports, team projects.

AER E 161H. Numerical, Graphical and Laboratory Techniques for Aerospace Engineering: Honors.
(3-2) Cr. 4. F.S. *Prereq: AER E 160 or equivalent course*
Computer solutions to aerospace engineering problems using the FORTRAN language and Matlab(R), with emphasis on numerical methods. Solid modeling with emphasis on aerospace design. Analysis of basic mathematical models and engineering problem solving. Written and oral technical reports, team projects.

AER E 192. Aerospace Seminar.
Cr. R. S.
Experimental lab set-up, graphical skills. Academic program planning.

AER E 192H. Aerospace Seminar: Honors..
Cr. R. S.
Experimental lab set-up, graphical skills. Academic program planning.

AER E 261. Introduction to Performance and Design.
(4-0) Cr. 4. F.S. *Prereq: AER E 161, MATH 166, PHYS 221*
Introduction to aerospace disciplinary topics, including: aerodynamics, structures, propulsion, and flight dynamics with emphasis on performance. Written technical reports and team projects.

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 291. Aerospace Advising Seminar.
Cr. R. F.
Academic program planning. Offered on a satisfactory-fail basis only.

AER E 292. Aerospace Advising Seminar.
Cr. R. S.
Academic program planning. Offered on a satisfactory-fail basis only.

AER E 298. Cooperative Education.
Cr. R. F.S.SS. *Prereq: Permission of department and Engineering Career Services*
First professional work period in the cooperative education program. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

AER E 301. Flight Experience.
Cr. R. F. *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. *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. S. *Prereq: AER E 310, M E 231*
Review of thermodynamics, energy equation, compressible flow, isentropic flow, normal and oblique shocks, Mach waves, expansion fans, ducts and nozzles, compressible slender body theory. Nonmajor graduate credit.

AER E 321. Flight Structures Analysis.
(3-0) Cr. 3. F. *Prereq: E M 324*
Determination of flight loads. Materials selection for flight applications. Analysis of flight structures including trusses, beams, frames, and shear panels employing classical and finite element methods. Nonmajor graduate credit.

AER E 321L. Aerospace Structures Laboratory.
(1-2) Cr. 2. F. *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. S. *Prereq: AER E 355*
Linear system analysis. Control system designs using root-locus and frequency response methods. Applications in flight control systems. Nonmajor graduate credit.

AER E 344. Aerodynamics and Propulsion Laboratory.
(2-2) Cr. 3. S. *Prereq: AER E 310 and 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: E M 345, AER E 261, Credit or enrollment in AER E 310*
Introduction to astrodynamics. Two-body motion. Geocentric, lunar and interplanetary trajectories and applications. Launch and atmospheric re-entry trajectories. Nonmajor graduate credit.

AER E 355. Aircraft Flight Dynamics and Control.
(3-0) Cr. 3. F. *Prereq: AER E 261, MATH 267, E M 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. Nonmajor graduate credit.

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

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. Nonmajor graduate credit.

AER E 391. Aerospace Advising Seminar.
Cr. R. F.S.
Academic program planning. Offered on a satisfactory-fail basis only.

AER E 392. Aerospace Advising Seminar.
Cr. R. S.
Academic program planning. Offered on a satisfactory-fail basis only.

AER E 396. Summer Internship.
Cr. R. Repeatable. SS. *Prereq: Permission of department and Engineering Career Services*
Summer professional work period. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

AER E 397. Engineering Internship.
Cr. R. Repeatable. F.S. *Prereq: Permission of department and Engineering Career Services*
Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only. Professional work period, one semester maximum per academic year.

AER E 398. Cooperative Education.
Cr. R. F.S.SS. *Prereq: AER E 298, permission of department and Engineering Career Services*
Second professional work period in the cooperative education program. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

AER E 411. Aerospace Vehicle Propulsion I.
(3-0) Cr. 3. F. *Prereq: AER E 311*
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 turbojets and turbofans. Rocket engines and ramjet principles. Nonmajor graduate credit.

AER E 412. Aerospace Vehicle Propulsion II.
(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. Nonmajor graduate credit.

AER E 417. Experimental Mechanics.
(Cross-listed with E M). (2-2) Cr. 3. Alt. F., offered 2012. *Prereq: E M 324*
Introduction of different aspects of measuring deformation, strains, and stress for practical engineering problems. Strain gage theory and application. Selected laboratory experiments. Nonmajor graduate credit.

AER E 421. Advanced Flight Structures.
(2.5-1) Cr. 3. 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. Nonmajor graduate credit.

AER E 422. Vibrations and Aeroelasticity.
(3-0) Cr. 3. Alt. S., offered 2012. *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. Nonmajor graduate credit.

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. Nonmajor graduate credit.

AER E 426. Design of Aerospace Structures.
(1-6) Cr. 3. S. *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. Nonmajor graduate credit.

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. Nonmajor graduate credit.

AER E 442. V/STOL Aerodynamics and Performance.
(3-0) Cr. 3. F. *Prereq: AER E 355*
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. Nonmajor graduate credit.

AER E 446. Computational Fluid Mechanics and Heat Transfer I.
(Dual-listed with AER E 546). (3-0) Cr. 3. F. *Prereq: AER E 161, AER E 310*
Basic concepts of discretization, consistency, and stability. Explicit and implicit methods for ordinary diffential equations. Methods for each type of partial differential equation. Iterative solution methods; curvilinear grids. Examples of basic algorithms. Nonmajor graduate credit.

AER E 448. Fluid Dynamics of Turbomachinery.
(Cross-listed with M E). (3-0) Cr. 3. S. *Prereq: M E 335 or equivalent*
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. Nonmajor graduate credit.

AER E 451. Astrodynamics II.
(3-0) Cr. 3. F.S. *Prereq: AER E 351*
Simple orbit determination and prediction. Advanced orbit maneuvers, single-, double-, and triple-impulse; fixed-impulse, finite-duration. 3-D rigid-body dynamics, Euler's equations, satellite stabilization and attitude control. Earth gravity field models and gravity harmonics, orbit perturbations, variational methods, relative orbital mechanics, Clohessy-Wiltshire equations. Nonmajor graduate credit.

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 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. Nonmajor graduate credit.

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, missile, and space systems. Preliminary design of aerospace vehicles. Engineering Ethics.

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. Nonmajor graduate credit.

AER E 466. Multidisciplinary Engineering Design.
(Cross-listed with A 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 and receive 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, CPR E, E E, I E, MAT E, M E). (1-4) Cr. 3. Repeatable, maximum of 2 times. F.S. *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 481. Advanced Wind Energy: Technology and Design.
(3-0) Cr. 3. F. *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 an structural load estimation, wind resource characterization wind farm design, optimization. Nonmajor graduate credit.

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

AER E 491. Aerospace Advising Seminar.
Cr. R. F.S.
Academic program planning.

AER E 498. Cooperative Education.
Cr. R. Repeatable. F.S.SS. *Prereq: AER E 398, permission of department and Engineering Career Services*
Third and subsequent professional work periods in the cooperative education program. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

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 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.
(Cross-listed with E M). (3-2) Cr. 4. Alt. S., offered 2012. *Prereq: E M 510 or E M 514 or E M 516*
Fundamental concepts for force, displacement, stress, and strain measurements. Strain gages. Full field deformation measurements with laser interferometry and digital image processing. Advanced experimental concepts at the micro and nano scale regimes.

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. *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 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. Alt. S., offered 2012. *Prereq: AER E 311*
Thermodynamics of compressible flow. Viscous and inviscid compressible flow equations. One dimensional steady flow; isentropic flow, normal shock waves oblique and curved shocks. Method of characteristics. Subsonic, transonic, supersonic and hypersonic flows. Compressible boundary layers.

AER E 541. Incompressible Flow Aerodynamics.
(3-0) Cr. 3. F. *Prereq: AER E 311 or M E 335*
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. Advance Experimental Technique for Thermal-Fluid Studies.
(3-0) Cr. 3. Alt. F., offered 2013. *Prereq: AER E 311 or M E 335 or E M 378*
Introduction of 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, Holograph PIV, microscopic PIV); laser induced fluorescence; pressure sensitive painting, temperature sensitive painting; molecular tagging velocimetry; molecular tagging thermometry. Extensive application and demonstration laboratory experiments will be included.

AER E 546. Computational Fluid Mechanics and Heat Transfer I.
(Dual-listed with AER E 446). (3-0) Cr. 3. F. *Prereq: AER E 161, AER E 310*
Basic concepts of discretization, consistency, and stability. Explicit and implicit methods for ordinary diffential equations. Methods for each type of partial differential equation. Iterative solution methods; curvilinear grids. Examples of basic algorithms. Nonmajor graduate credit.

AER E 547. Computational Fluid Mechanics and Heat Transfer II.
(Cross-listed with M E). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq: AER E 546 or AER E 546*
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 564. Fracture and Fatigue.
(Cross-listed with M S E, M E, E M). (3-0) Cr. 3. Alt. F., offered 2012. *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 I E, E 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 and 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 569. Mechanics of Composite and Combined Materials.
(Cross-listed with M S E, E M). (3-0) Cr. 3. Alt. S., offered 2012. *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 2013. *Prereq: E M 378, E M 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. Alt. S., offered 2012. *Prereq: AER E 543 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, MATH, 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, MATH, 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 MATH, 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, MATH, M E). (3-0) Cr. 3. F. *Prereq: E E 475 or AER E 432 or M E 411 or 414 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, MATH, M E). (3-0) Cr. 3. F. *Prereq: E E 324 or AER E 331 or MATH 415; and MATH 307*
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, MATH, M E). (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. S. *Prereq: MATH 267*
Mathematical perturbation methods with applications to ordinary 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 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. S. *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, Tayor-Couette flow, centrifugal instability, double diffusion.

AER E 647. Advanced High Speed Computational Fluid Dynamics.
(Cross-listed with M E). (3-0) Cr. 3. Alt. S., offered 2013. *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.