AEROSPACE ENGINEERING

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Academic Programs

Program name	Program type
Aerospace Engineering	BS, MS

The mission of the Aerospace Engineering Department is to collaborate with the Aerospace Industry to build partnerships which promote excellence and innovation to serve diverse communities. We work as a team to provide an excellent Learn-by-Doing, systems and design focused engineering education; graduating Day One-ready professionals.

We accomplish our mission using a laboratory-based, hands-on approach to education students. This approach, coupled with a systems view of engineering, is encouraged through coursework and a group-based capstone design experience. This educational philosophy yields engineers capable of working in positions of technical responsibility and leadership in a modern multidisciplinary, systems-based industry.

The Bachelor of Science degree in Aerospace Engineering prepares students for engineering work in the exciting aerospace industry. The problems faced by the aerospace industry offer an unusual engineering challenge. Much of the analysis and testing must be accomplished at the very frontiers of technology and performance. Nevertheless, complex aerospace systems must be designed and manufactured; thus, an exceptionally wide range of engineering and problem solving abilities is required. Aerospace Engineering graduates obtain employment in all areas of the aerospace industry with a strong focus on aircraft and spacecraft design.

Aerospace Engineering students can choose between an Aeronautics or Astronautics concentration. Within Aeronautics, students learn the fundamentals of aerodynamics, flight mechanics, materials, structures, propulsion, and stability and control. Within Astronautics, students learn the fundamentals of orbital mechanics, space environment, space structures, telecommunications, attitude dynamics and control, and rocket propulsion. Both concentrations culminate with a Senior Design capstone course where students put theory into practice using a disciplined systems engineering approach to either aircraft or spacecraft design.

The BS degree program in Aerospace Engineering is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org/. It places emphasis on both analysis and design, with supplementary basic work in laboratory projects. Throughout the entire program there is constant interplay between theory and application. Opportunities are available for advanced elective work in the student's field of special interest.

The program maintains laboratory facilities for fabrication, air breathing and space propulsion, structures and composites, aerodynamics, dynamics and control, flight simulation and flight test, aerothermodynamics, advanced computation, and design.

Aerospace students may participate in two student chapters of national professional societies–the American Institute of Aeronautics and Astronautics and the Society for the Advancement of Material and Process Engineering. There is also a student chapter of the national aerospace engineering honor society, Sigma Gamma Tau. In addition, students have the opportunity to work on CubeSats and Autonomous Flight Systems, through other club activities or faculty research.

Undergraduate Program
BS Aerospace Engineering

The Bachelor of Science degree in Aerospace Engineering prepares students for engineering work in the exciting aerospace industry. The aerospace industry is known for designing and building complex systems which push the limits of technology. Therefore a strong emphasis is placed on turning theory into practice and problem solving using a disciplined systems engineering approach. The program's faculty have developed a number of educational objectives to support this mission. These objectives are:

- Be life-long learners who continue to pursue professional development;
- Participate and thrive in a multi-disciplinary , systems-oriented work environment;
- Contribute to the solution of complex technical problems that exist in the global aerospace industry; and
- Understand their ethical role as a professional engineer and strive to promote a practice of integrity and foster diversity, equity, and inclusion in the workplace.

Concentrations

Aeronautics
Astronautics

Graduate Program
MS Aerospace Engineering

Characteristics

Emphasizes engineering science and research activity. Graduates have an increased capability for complex research, development, and innovative design, and are prepared for further study in engineering, leading to the Doctor of Engineering or Ph.D. or advanced positions within industry.

Program of Study

A thesis is required as a culminating experience. Students work with their advisor and the Department Graduate Coordinator to develop a program of study which supports their thesis topic. A thesis topic would typically be in an area such as: dynamics and control, fluid dynamics and aerodynamics, multidisciplinary design and optimization, aerospace propulsion, aerospace structures, and systems engineering.

For the most recent, comprehensive list of courses offered by the department, please contact the Department Graduate Coordinator or see the listing at https://aero.calpoly.edu (http://aero.calpoly.edu/).

Blended BS + MS Aerospace Engineering Program

A blended program provides an accelerated route to a graduate professional degree, with simultaneous conferring of both Bachelor's and Master's degrees. Students in the blended program are provided with a seamless process whereby they can progress from undergraduate to graduate status. Students are required to complete all requirements for both degrees, including senior project for the Bachelor's degree.

A blended program is available for MS Aerospace Engineering.

Eligibility

Students majoring in BS Aerospace Engineering are eligible for the blended program in MS Aerospace Engineering.

Participation in a blended program is based upon prior academic performance and other measures of professional promise. Refer to Graduate Education (https://catalog.calpoly.edu/graduateeducation/#graduateandpostbaccalaureateadmissionrequirements/) for more information and for the minimum criteria required to be eligible for a blended program at Cal Poly. Contact the Graduate Program Coordinator in the Aerospace Engineering department for any additional eligibility criteria.

AERO Courses

AERO 121. Aerospace Fundamentals. 2 units
Term Typically Offered: F
Introduction to the engineering profession including the aeronautical and aerospace fields. Engineering approach to problem-solving and analysis of data obtained from experiments. Basic nomenclature and design criteria used in the aerospace industry. Applications to basic problems in the field. 1 lecture, 1 laboratory.

AERO 200. Special Problems for Undergraduates. 1-4 units
Term Typically Offered: F, W, SP
Prerequisite: Consent of department head.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units.

AERO 215. Introduction to Aerospace Design. 2 units
Term Typically Offered: F, W
Prerequisite: AERO 121 and MATH 143. Recommended: IME 144.

Introduction to problem solving techniques and team-centered design projects in aerospace engineering. Primary emphasis on the solutions of design problems in aerospace engineering using computers. 2 laboratories.

AERO 220. Aerospace Systems Engineering and Integration. 1 unit
Term Typically Offered: W, SP
Prerequisite: AERO 121.

Project-based study of fundamental systems engineering concepts including sub-system interface requirements, verification and validation, modeling/analysis/design, and implementation of complex aerospace systems. 1 laboratory.

AERO 270. Selected Topics. 1-4 units
Term Typically Offered: TBD
Prerequisite: Open to undergraduate students and consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

AERO 299. Aerospace Thermodynamics. 4 units
Term Typically Offered: SP
Prerequisite: ME 212. Corequisite: AERO 300. Recommended: AERO 215.

Basics of thermodynamics, energy, systems and control volume analysis. First law, second law, phase change and energy analysis for aerospace-relevant applications. Entropy and exergy, cycle analysis (Rankine, Brayton, turbojets and turbofans). Not open to students with credit in AERO 301. 3 lectures, 1 laboratory.

AERO 300. Aerospace Engineering Analysis. 5 units
Term Typically Offered: SP
Prerequisite: AERO 215, MATH 244, ME 211, and PHYS 133.

Analytical and numerical methods for aerospace engineering problems. Topics include vector calculus, linear algebra, ordinary and partial differential equations, and Fourier transforms. Computer tools and numerical methods as applied to problems in aerodynamics, structures, stability and control and astronautics. 4 lectures, 1 laboratory.

AERO 302. Aerospace Fluid Mechanics. 4 units
Term Typically Offered: F
Prerequisite: ME 212. Corequisite: AERO 300. Recommended: AERO 215; and AERO 299 or AERO 301.

Properties of fluids, statics, mass/energy/momentum for aeronautical applications, external aerodynamics (lift and drag), dimensional analysis for scale testing, introduction to differential analysis and Navier-Stokes equations, basics of laminar and turbulent boundary layers. 3 lectures, 1 laboratory.

AERO 303. Aerospace Gas Dynamics and Heat Transfer. 4 units
Term Typically Offered: W
Prerequisite: AERO 299 or AERO 301; and AERO 302.

Basics of heat transfer and approaches to problem solving, steady heat conduction, convection (forced and natural), heat exchanger design, shock waves and compressible flow in nozzles and diffusers (normal, oblique, expansion waves), thermal radiation and applications. 3 lectures, 1 laboratory.

AERO 306. Aerodynamics and Flight Performance. 4 units
Term Typically Offered: F
Prerequisite: AERO 215; AERO 299 or AERO 301. Concurrent: AERO 302.

Introduction to theoretical aerodynamics. Primary emphasis in the subsonic region, including compressibility effects. Basic aerodynamic theory: Airfoil theory, wing theory, lift and drag. Team-centered aerodynamic design. Flight performance. 4 lectures.

AERO 307. Experimental Aerodynamics. 2 units
Term Typically Offered: SP
Prerequisite: AERO 302, AERO 306, ENGL 149.

Wind tunnel testing of basic aerodynamic properties of airfoils, finite wings, aircraft or spacecraft models, and vehicle flight performance. Emphasis on both static and dynamic responses of aircraft. Various measurement techniques, data reduction schemes, and analysis methods. 2 laboratories.

AERO 310. Air and Space. 4 units
Term Typically Offered: F,W,SP,SU
2020-21 or later: Upper-Div GE Area B
2019-20 or earlier catalog: GE Area B5, B6, or B7
Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; completion of GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs); and one course in GE Area B4 with a grade of C- or better (GE Area B1 for students on the 2019-20 or earlier catalogs).

Technological developments of modern aircraft and spacecraft through physics of flight equations, mission analysis, propulsion, structures, materials, and control systems for civil and military aircraft/spacecraft. Synthesis of current and future aerospace technologies through emerging ethical considerations, and global impact. 4 lectures. Course may be offered in classroom-based or online format. Crosslisted as AERO/HNRS 310. Fulfills GE Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

AERO 320. Fundamentals of Dynamics and Control. 4 units
Term Typically Offered: F
Prerequisite: AERO 300 and ME 212.

Introduction to six degree of freedom rigid body dynamic and kinematic equations of motion, including coordinate transformations, Euler angles and quaternions for aerospace vehicles. Linearization and dynamic system theory and stability. Introduction to linear control theory, controller design and analysis. 4 lectures.

AERO 321. Experimental Sensors, Actuators and Control. 1 unit
Term Typically Offered: F
Prerequisite: AERO 300. Recommended: EE 201 and EE 251.

Experiments in translational and rotational dynamics, structural, thermal, and flow control. Comparison of modeling/simulation results to experimental data. Role of actuators, sensors, noise, feedback, and supporting instrumentation hardware and software. Introduction to technical communication. 1 laboratory.

AERO 331. Aerospace Structural Analysis I. 4 units
Term Typically Offered: W
Prerequisite: AERO 300, CE 207 or CE 208, and ME 212.

Deflection analysis. Principles of fictitious displacement, virtual work, and unit load method. Energy methods: Castigliano's theorem, Maxwell-Betti reciprocal theorem, minimum principles, Rayleigh-Ritz's method and Galerkin's method. Stress analysis of aircraft and spacecraft components. 4 lectures.

AERO 350. Fundamentals of Systems Engineering. 2 units
Term Typically Offered: W, SP
Prerequisite: AERO 220.

Systems engineering principles and methods applied to the design of aerospace systems. System-level requirements, user needs and stakeholder constraints, component-level requirements, and requirements breakdown structure. Project planning and tracking. Trade studies for design decision making. 2 lectures.

AERO 351. Introduction to Orbital Mechanics. 4 units
Term Typically Offered: F
Prerequisite: AERO 300 and ME 212.

Motion of a body in a central field. Keplerian Orbits. Orbital maneuvers. Interplanetary trajectories. 4 lectures.

AERO 354. Space Environment Laboratory. 2 units
Term Typically Offered: SP
Prerequisite: AERO 353 or AERO 355; and ENGL 149.

Laboratory examples of the effects of the space environment on a spacecraft and design considerations. Topics include the launch, vacuum, particulate, plasma, and radiation environments. All topics are applied to how the environment affects spacecraft design considerations. Not open to students with credit in AERO 356. 2 laboratories.

AERO 355. Space Environments I. 3 units
Term Typically Offered: W
Prerequisite: AERO 300.

Effects of the space environment on a spacecraft and design considerations. Lecture and laboratory topics include the launch, vacuum, neutral and particulate environments. Not open to students with credit in AERO 353 or AERO 354. 2 lectures, 1 laboratory.

AERO 356. Space Environments II. 3 units
Term Typically Offered: SP
Prerequisite: AERO 299 or AERO 301; and AERO 355.

Effects of the space environment on a spacecraft and design considerations. Lecture and laboratory topics include the radiation, plasma, and thermal environments and the synergistic effects. Not open to students with credit in AERO 353 or AERO 354. 2 lectures, 1 laboratory.

AERO 360. Creative Problem Solving in Engineering Design. 2 units
Term Typically Offered: W
Prerequisite: PSY 350.

The creative problem solving process for an engineering design team. How to explore context and causes as part of defining a design problem; the principles of brainstorming, synthesis, and judgment. Role of iteration, implementation, and communication. Importance of a diverse view, including: customers, products, processes, systems, ethics, and professional responsibility. Team-based applications to case studies and real-world engineering design problems. 2 laboratories.

AERO 400. Special Problems for Advanced Undergraduates. 1-4 units
Term Typically Offered: F,W,SP,SU
Prerequisite: Consent of instructor.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 8 units.

AERO 401. Propulsion Systems. 5 units
Term Typically Offered: F
Prerequisite: AERO 303, CHEM 124.

Power plant types, components, characteristics, and requirements. Principles of thrust and energy utilization. Thermodynamic processes and performance of turboprop, turboshaft, turbofan, turbojet, ramjet, and rocket engines. 4 lectures, 1 laboratory.

AERO 402. Spacecraft Propulsion Systems. 5 units
Term Typically Offered: F
Prerequisite: AERO 303; AERO 353 or AERO 355; and CHEM 124.

Effects of the propulsion subsystem on spacecraft design. Introduction to air breathing propulsion systems. Topics include basic rocket performance, monopropellant thrusters, bipropellant thrusters, electric thrusters, thruster placement, plumbing, tank sizing and design, system layout, component design, and systems integration. 4 lectures, 1 laboratory.

AERO 405. Supersonic and Hypersonic Aerodynamics. 4 units
Term Typically Offered: SP
Prerequisite: AERO 303; AERO 306 or AERO 353 or AERO 355.

Review of gas dynamics, shock-wave and boundary-layer interaction, aerodynamic design. 2-dimensional supersonic flows around thin airfoil; finite wing in supersonic flow. Local surface inclination methods for high-speed flight, boundary-layer and aerodynamic heating, viscous interactions. 4 lectures.

AERO 406. Applied Computational Fluid Dynamics. 4 units
Term Typically Offered: F
Prerequisite: AERO 302 and AERO 306.

Application of Computational Fluid Dynamics to study a range of problems relating to applications in aerospace and automotive engineering. Grid generation, sources of errors in CFD studies, boundary conditions, 2D and 3D external flows, and turbulence modeling. 2 lectures, 2 laboratories.

AERO 407. Reentry Aerodynamics. 4 units
Term Typically Offered: W
Prerequisite: AERO 303.

Near planet environments. Transition from orbital to aero-dynamic motion. Aerodynamic heating and effects on design. 4 lectures.

AERO 408. Plasma Applications in Aerospace. 4 units
Term Typically Offered: F
Prerequisite: PHYS 123 or PHYS 133 and senior standing, or graduate standing.

Plasma applications in aerospace technology and operations including hypersonics, space weather, shielding, stealth, communications, power, and aerodynamics. Computational modelling of plasma and plasma theory. 4 lectures.

AERO 409. Flight Test. 4 units
Term Typically Offered: W
Prerequisite: AERO 306. Concurrent: AERO 320.

Overview of flight tests, test equations, and supporting facilities. Principles of team-centered flight testing with applications to performance, stability and control, and avionics systems testing. Test planning, instrumentation, data analysis and reports. 2 lectures, 2 laboratories.

AERO 420. Aircraft Dynamics and Control. 4 units
Term Typically Offered: W
Prerequisite: AERO 306 and AERO 320.

Newton's 6-degree-of-freedom equations of motion applied to aerospace vehicles. Stability and control derivatives, reference frames, steady-state and perturbed dynamic analyses applied to aerospace vehicles. Stability and control design principles applied to transfer functions, state-space, and modal system dynamics. 4 lectures.

AERO 421. Spacecraft Attitude Dynamics and Control. 4 units
Term Typically Offered: SP
Prerequisite: AERO 320 and AERO 351.

Introduction to spacecraft attitude dynamics and control. Momentum exchange devices and bang-bang thruster control. Attitude determination (GPS), maneuvers and station keeping. Fundamentals of guidance and navigation systems. Analysis and design of control systems for aerospace vehicles. 4 lectures.

AERO 425. Aircraft Performance. 4 units
Term Typically Offered: F
Prerequisite: ME 212, AERO 306, AERO 300.

Fundamentals of propeller and jet aircraft performance. Steady and accelerated flight. Equations of motion. Level flight, gliding, climbing, driftdown. Takeoff and landing. Federal Aviation Regulations (FARs). Range and endurance. Payload-range diagram. Maneuvering. V-n diagram. Turning and pull-ups. Stall and spin behavior. Energy methods. 4 lectures.

AERO 431. Aerospace Structural Analysis II. 4 units
Term Typically Offered: SP
Prerequisite: AERO 331.

Basic equations of elasticity with applications to typical aerospace structures. Concepts studied include analysis of aircraft and aerospace structures; airworthiness and airframe loads; structural constraints; elementary aeroelasticity; structural instability; introduction to modern fatigue; fracture mechanics; and composite structures analysis. 4 lectures.

AERO 432. Advanced Composite Structures Analysis. 4 units
Term Typically Offered: F
Prerequisite: AERO 331.

Review of isotropic material behavior. Behavior of unidirectional fiber composites. Properties of short-fiber composites and orthotropic lamina. Analysis of laminated composites. Stresses and strains of composites. Strength and hygrothermal behavior of composite materials. 3 lectures, 1 laboratory.

AERO 433. Experimental Stress Analysis. 1 unit
Term Typically Offered: F, W, SP
Prerequisite: AERO 331, AERO 431.

Employing the knowledge of stress analysis and aerospace structural analysis in an individual and group design project dealing with aerospace structures. 1 laboratory.

AERO 434. Aerospace Structural Analysis III. 4 units
Term Typically Offered: F
Prerequisite: AERO 431.

Analysis and design applications for aircraft and spacecraft structures. Stress concentrations, fatigue, and fracture mechanics. Structural dynamics. Framed structures, plates and shells. Composite applications. 4 lectures.

AERO 435. Aerospace Numerical Analysis. 4 units
Term Typically Offered: F
Prerequisite: AERO 300, AERO 331.

Taylor series. Finite difference calculus. Interpolation and extrapolation. Finite difference method. Basic equations of elasticity. Global stiffness matrix. Rayleigh-Ritz method. Galerkin method. Bernoulli-Euler beam element. Finite element formulation. Dynamic analysis. 3 lectures, 1 laboratory.

AERO 443. Aircraft Design I. 3 units
Term Typically Offered: F
Prerequisite: IME 144; AERO 215; AERO 306; AERO 350; AERO 405; AERO 420; and AERO 431. Concurrent: AERO 401.

System and conceptual design of an aircraft using design and calculation techniques developed in previous aerospace engineering courses. Determination of system requirements and design of a flight vehicle, including its structures and systems. Preparation of necessary drawings, briefings, and reports. Field trip required. 3 laboratories.

AERO 444. Aircraft Design II. 3 units
Term Typically Offered: W
Prerequisite: AERO 443.

Preliminary layout of a typical aircraft vehicle using design and calculation techniques developed in previous aerospace engineering courses. Design of a flight vehicle, including its structures and systems. Preparation of necessary drawings and a report. Field trip required. 3 laboratories.

AERO 445. Aircraft Design III. 3 units
Term Typically Offered: SP
Prerequisite: AERO 444.

Preliminary layout of a typical aircraft vehicle using design and calculation techniques developed in previous aerospace engineering courses. Design of a flight vehicle, including its structures and systems. Preparation of necessary drawings and a report. Field trip required. 3 laboratories.

AERO 446. Spacecraft Electrical and Electric Systems. 4 units
Term Typically Offered: SP
Prerequisite: AERO 353 or AERO 355; ME 212; EE 201 and EE 251.

Basic satellite types and their applications. Major subsystems of a satellite system including ground support and launch systems. Interactions between subsystems and their effects on the overall system design. Detailed analysis of key subsystems on a spacecraft with special emphasis on power and communications subsystems. 4 lectures.

AERO 447. Spacecraft Design I. 3 units
Term Typically Offered: F
Prerequisite: IME 144; AERO 215; AERO 303; AERO 350; AERO 351; AERO 420 or AERO 421; AERO 431; and AERO 446. Concurrent: AERO 402. Recommended: AERO 353 or AERO 355.

System and conceptual design of a space vehicle using design and calculations techniques in previous aerospace engineering courses. Determination of system requirements and design of a spacecraft or system of spacecraft. Preparation of necessary drawings, briefings and reports. Field trip required. 3 laboratories.

AERO 448. Spacecraft Design II. 3 units
Term Typically Offered: W
Prerequisite: AERO 447.

Preliminary layout of typical space vehicle using design and calculation techniques developed in previous aerospace engineering courses. Design of selected components and preparation of necessary drawings. 3 laboratories. Field trip required.

AERO 449. Spacecraft Design III. 3 units
Term Typically Offered: SP
Prerequisite: AERO 448.

Preliminary layout of typical space vehicle using design and calculation techniques developed in previous aerospace engineering courses. Design of selected components and preparation of necessary drawings. Field trip required. 3 laboratories.

AERO 450. Introduction to Aerospace Systems Engineering. 4 units
Term Typically Offered: W
Prerequisite: Senior standing or graduate standing.

Aerospace systems and subsystems. Systems integration. Development of system requirements. Analysis, modeling and simulation of complex systems. Project management. Cost analysis. Optimization and trade studies. 4 lectures.

AERO 452. Spaceflight Dynamics II. 4 units
Term Typically Offered: F
Prerequisite: AERO 351.

Relative orbital motion and rendezvous, linearization of the equations of motion. Clohessy-Wiltshire equations. Two-impulse rendezvous. Aspherocity of the earth, aerodynamic drag, solar radiation pressure, and n-body perturbations on an orbit. Encke, Cowell, and Variation of Parameters solution techniques. Speciality orbit due to perturbations such as low thrust trajectories, sun-synchronous, and molynia orbits. 4 lectures.

AERO 455. Introduction to Human Spaceflight. 4 units
Term Typically Offered: SP
Prerequisite: AERO 443 or AERO 447 or graduate standing.
Recommended: AERO 351; AERO 353 or AERO 355 and AERO 356.

Requirements and considerations for human spaceflight design and operations. Effects of the spaceflight environment on the human body and countermeasures to mitigate those effects. Designing a spacecraft for the human payload focusing on space operations. 4 lectures.

AERO 460. Aerospace Engineering Professional Preparation. 1 unit
Term Typically Offered: F
Prerequisite: Senior standing.

Topics on professional development for student success including resume building and career prospecting, current events in the aerospace industry, graduate studies, engineering ethics, intellectual property, non-disclosure agreements, teamwork, and innovation and entrepreneurship. 1 lecture.

AERO 465. Aerospace Systems Senior Laboratory. 1 unit
Term Typically Offered: F, W, SP
Prerequisite: AERO 303, AERO 320, AERO 431 and senior standing.

Culminating laboratory based experience. Experiments require the integration of the many disciplines in Aerospace Engineering. The successful completion of each experiment requires synthesis and integration of the fundamental concepts of the engineering sciences. Experimentation in the areas of aeroelasticity, active vibration control, inertial navigation, thermal control, hardware-in-the-loop simulation, and momentum exchange. 1 laboratory.

AERO 470. Selected Advanced Topics. 1-4 units
Term Typically Offered: TBD
Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

AERO 471. Selected Advanced Laboratory. 1-4 units
Term Typically Offered: TBD
Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

AERO 493. Cooperative Education Experience. 2 units
Term Typically Offered: F,W,SP,SU
CR/NC
Prerequisite: Sophomore standing and consent of instructor.

Part-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 6 units.

AERO 494. Cooperative Education Experience. 6 units
Term Typically Offered: F,W,SP,SU
CR/NC
Prerequisite: Sophomore standing and consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 18 units.

AERO 495. Cooperative Education Experience. 12 units
Term Typically Offered: F,W,SP,SU
CR/NC
Prerequisite: Sophomore standing and consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. A more fully developed formal report and evaluation by work supervisor required. Credit/No Credit grading only. No major credit allowed; total credit limited to 24 units.

AERO 500. Individual Study. 1-4 units
Term Typically Offered: F,W,SP,SU
Prerequisite: Consent of department head, graduate advisor and supervising faculty member.

Advanced study planned and completed under the direction of a member of the department faculty. Open only to graduate students who have demonstrated ability to do independent work. Enrollment by petition. Total credit limited to 12 units.

AERO 513. Applications of Remotely Piloted Aircraft Systems. 4 units
Term Typically Offered: F
Prerequisite: AERO 306 or AERO 351 or graduate standing.

Engineering development and analysis of Remotely Piloted Aircraft Systems (RPAS) as airborne tools for societal benefit. Use of RPAS for military, public service, and commercial purposes. Characterization of missions and applications. Development of system requirements and concepts of operation. Evaluation of relative merits and limitations of RPAS. 4 lectures.

AERO 515. Continuum Mechanics. 4 units
Term Typically Offered: SP
Prerequisite: Graduate standing or consent of instructor.

Vectors and tensors stress analysis. Analysis of deformation. Velocity fields and compatibility conditions. Constitutive equations. Isotropy. Mechanical properties of real fluids and solids. Field equations and boundary conditions in fluid mechanics problems and applications in elasticity. Active remodeling of structures. 4 seminars.

AERO 522. Boundary-Layer Theory. 4 units
Term Typically Offered: SP
Prerequisite: AERO 302 or graduate standing.

Concept of boundary-layer. Boundary-layer equations, similarity transformation, integral and differential methods for steady, two-dimensional laminar and turbulent boundary layers. 4 lectures.

AERO 525. Computational Fluid Dynamics. 4 units
Term Typically Offered: W
Prerequisite: AERO 303 or graduate standing.

Classification of partial differential equations. Numerical methods applicable to the solution of elliptic, parabolic, and hyperbolic partial differential equations. Consideration of accuracy and stability of numerical methods. Application to the fundamental equations of fluid dynamics, grid generation, turbulence modeling. 4 lectures.

AERO 526. Spacecraft Thermal/Fluid Control. 4 units
Term Typically Offered: W
Prerequisite: AERO 299 or AERO 301; AERO 302; AERO 303; or graduate standing.

Satellite thermal/fluid control hardware. Governing equations for flow and heat transfer. Surface tension and liquid/vapor interface. Heat transfer by free convection, forced convection and radiation in low-gravity environment. Heat pipes. Capillary-pumped loops. Cryogenic systems. Fluid management in space. 4 lectures.

AERO 532. Advanced Aerospace Composite Design. 4 units
Term Typically Offered: W
Prerequisite: Graduate standing or consent of instructor.

Behavior of composite materials. Bending, buckling, and vibration of laminated plates. Fatigue and fracture mechanics analysis of composite structures. Optimum design of composite pressure vessels. 2 seminars, 2 laboratories.

AERO 533. Finite Elements for Aerospace Structural Analysis. 4 units
Term Typically Offered: SP
Prerequisite: AERO 431.

Overview of theoretical and applied methods of finite element analysis for aerospace structures including composite and light weight structures. Topics include basic equations of elasticity, solutions of linear systems of equations transformation, global stiffness matrix, Bernoulli-Euler element, plane stress triangles, finite element formulation, isoparametric elements, alternative formulation, eigenvalue problems and dynamic analysis. 3 lectures, 1 laboratory.

AERO 534. Aerospace Structural Dynamics Analysis. 4 units
Term Typically Offered: F
Prerequisite: Graduate standing.

Structural dynamics and aeroelasticity of flight vehicles. Vibration and forced response of continuous structures. Introduction to unsteady aerodynamic analysis methods. Normal-Mode Method and Modal Analysis. Framed structures and rigid body structures. Airworthiness and aeroelasticity. Random Vibrations. 3 lectures, 1 laboratory.

AERO 535. Advanced Aerospace Structural Analysis. 4 units
Term Typically Offered: SP
Prerequisite: Graduate standing or consent of instructor.

Types of failure. Theories of failure. Stability of structures. Advanced flight vehicle and fracture mechanics analysis and design. Fundamentals and applications of modern fatigue analysis in the aerospace industry. 3 lectures, 1 laboratory.

AERO 540. Elements of Rocket Propulsion. 4 units
Term Typically Offered: W
Prerequisite: AERO 303, AERO 401 or 402; or graduate standing.

Thrust and impulse equations, propellant composition and mixture ratios, nozzle expansion ratios, solid and liquid propellant combustion, internal ballistics, thermo-chemical computations, chemical kinetics, and combustion instability, nozzle design and exhaust plumes. 4 seminars.

AERO 541. Air Breathing Propulsion. 4 units
Term Typically Offered: SP
Prerequisite: AERO 401 or graduate standing.

Aerothermodynamics of propulsion systems, power plant selection and design, on-off design performance, component characterization, component design, component matching, optimization, and introduction to power plant and airframe integration systems for aircraft. 4 seminars.

AERO 548. Complexity in Engineered Systems. 4 units
Term Typically Offered: SP
Prerequisite: Graduate standing.

Relates systems engineering to complexity in the design and development of modern large engineered systems, with emphasis on aerospace applications. Covers methods currently available to address complexity, including systems thinking, model based systems engineering and life cycle governance. 4 lectures.

AERO 549. Systems Engineering Applications. 4 units
Term Typically Offered: W
Prerequisite: AERO 450 or graduate standing.

Systems engineering principles and methods. Program planning, scheduling and budgeting, risk management, and design strategies to meet system/mission requirements. Quality function development and quality control concepts. Proposal development, evaluation, and selection. Not open to students with credit in AERO/IME 510 or AERO/IME 511. 4 lectures.

AERO 553. Advanced Control Theory. 4 units
Term Typically Offered: W
Prerequisite: AERO 320 or graduate standing.

Advanced control theory techniques. Analytical and computational methods applied to dynamic systems. State space system representation, solutions to dynamic systems, non-linear and linear stability analysis, full-state and output feedback, controllability and observability and advanced control topics (LQR/LQG, Kalman Filters, Adaptive Control, etc.). 4 lectures.

AERO 557. Advanced Orbital Mechanics. 4 units
Term Typically Offered: W
Prerequisite: AERO 351 or graduate standing.

Initial orbit determination using angles only methods. Various Solutions to Lambert's Problem. Orbit and transfer optimization, libration points, halo orbits, and secondary orbit perturbations. 4 lectures.

AERO 560. Advanced Spacecraft Dynamics and Control. 4 units
Term Typically Offered: W
Prerequisite: AERO 421 or graduate standing.

Attitude determination and control of rigid spacecraft via reaction wheels, control moment gyros and thrusters. Modeling, analysis and control of flexible spacecraft. Non-linear stability theory as applied to spacecraft. 4 lectures.

AERO 561. Vehicle Integration and Testing. 2 units
Term Typically Offered: F
Prerequisite: AERO 350 or AERO 446, or graduate standing.

Space vehicle integration requirements and procedures. Clean room requirements and operations. Quality control and inspection. Qualification and acceptance testing requirements. Test equipment. Vibration and shock testing. Space environment and thermal-vac testing. Development of test procedures. 1 lecture, 1 laboratory.

AERO 562. Space Operations. 2 units
Term Typically Offered: F
Prerequisite: AERO 350 or AERO 446, or graduate standing.

Launch operations and vehicle integration with launch vehicle. In-orbit operations and maneuvers. Spacecraft tracking. Telemetry and command. Ground systems. Failure detection and identification. Emergency operations. 1 lecture, 1 laboratory.

AERO 565. Advanced Topics in Aircraft Design. 4 units
Term Typically Offered: SP
Prerequisite: AERO 445 or graduate standing.

Application of advanced analytic engineering methods to aircraft design problems. Analysis and synthesis of advanced topics related to design of aircraft. 4 lectures.

AERO 566. Advanced Topics in Spacecraft Design. 4 units
Term Typically Offered: F
Prerequisite: AERO 449 or graduate standing.

Application of advanced engineering tools to the design of space vehicles. System architecture and mission design. Concept of operations. Requirements development and flow down. System and subsystems trade studies and preliminary design. 4 lectures.

AERO 568. Aerodynamic Research and Development I. 4 units
Term Typically Offered: W
Prerequisite: AERO 302 and AERO 406.

Immersive team-based approach to an aerodynamic research and development cycle. Theoretical work, preliminary design based upon computational fluid dynamics, and model manufacture. Advanced techniques in multi-variable wind tunnel tests. Validation of numerical work using correlation techniques. Field trip may be required. Total credit limited to 8 units. 2 lectures, 2 laboratories.

AERO 569. Aerodynamic Research and Development II. 4 units
Term Typically Offered: SP
Prerequisite: AERO 568.

Continuation of AERO 568. Single or multi-variable design optimization cycle based upon computational fluid dynamics. Numerical and experimental experimentation, high-fidelity validation and correlation of testing data, and archival-quality technical reporting of aerodynamic data and analysis. Total credit limited to 8 units. 2 lectures, 2 laboratories.

AERO 570. Selected Advanced Topics. 4 units
Term Typically Offered: TBD
Prerequisite: Graduate standing or consent of instructor.

Directed group study of selected topics for graduate students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 4 lectures.

AERO 571. Selected Advanced Topics Laboratory. 1-4 units
Term Typically Offered: TBD
Prerequisite: Graduate standing or consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

AERO 593. Cooperative Education Experience. 2 units
Term Typically Offered: TBD
CR/NC
Prerequisite: Graduate standing and consent of instructor.

Advanced study analysis and part-time work experience in student's career field; current innovations, practices, and problems in administration, supervision, and organization of business, industry, and government. Must have demonstrated ability to do independent work and research in career field. Credit/No Credit grading only.

AERO 594. Cooperative Education Experience. 6 units
Term Typically Offered: TBD
CR/NC
Prerequisite: Graduate standing and consent of instructor.

Advanced study analysis and full-time work experience in student's career field; current innovations, practices, and problems in administration, supervision, and organization of business, industry, and government. Must have demonstrated ability to do independent work and research in career field. Credit/No Credit grading only.

AERO 595. Cooperative Education Experience. 12 units
Term Typically Offered: F,W,SP,SU
CR/NC
Prerequisite: Graduate standing and consent of instructor.

Advanced study analysis and full-time work experience in student's career field; current innovations, practices, and problems in administration, supervision, and organization of business, industry, and government. Must have demonstrated ability to do independent work and research in career field. A fully-developed formal report and evaluation by work supervisor required. Credit/No Credit grading only.

AERO 599. Thesis (Design Project). 1-9 units
Term Typically Offered: F,W,SP,SU
Prerequisite: Graduate standing.

Each individual or group will be assigned a project for solution under faculty supervision as a requirement for the master's degree, culminating in a written report/thesis.