

University of Southern California
Viterbi School of Engineering
Astronautics and Space Technology

**B.Sc., Minor, M.Sc., Engineer, and Ph.D. Degrees and
Graduate Certificate in Astronautical Engineering**

The center of space technology is Los Angeles.

In the heart of Los Angeles,
the leader in space education is USC.

Space Science and Exploration

National Security Programs

Commercial Space

Realize your dream of studying and working
in astronautics and space technology
with USC's degree programs
in Astronautics and Space Technology

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Astronautics Program Faculty

Astronautics and Space Technology Division Chairman:
Prof. Mike Gruntman

Program Coordinators

Bachelor of Science:	Prof. Dan Erwin
Master of Science:	Prof. Mike Gruntman
Engineer:	Prof. Joseph Kunc
Doctor of Philosophy:	Prof. Joseph Kunc
Certificate:	Prof. Mike Gruntman

Program Faculty and Lecturers

Dr. Oscar Alvarez-Salazar (JPL)	Spacecraft Structural Dynamics
Prof. Elliot Axelband (USC&Hughes, ret.)	Systems Architecting
Prof. Robert F. Brodsky (USC&TRW, ret.)	Spacecraft and Space Mission Design
Dr. Alok Chatterjee (JPL)	Spacecraft Design
Prof. H.K. Cheng (USC)	Hypersonic and Supersonic Flows
Prof. Werner Dappen (USC)	Astronomy and Astrophysics
Prof. Dan Erwin (USC)	Spacecraft Propulsion, Astrodynamics, Plasma
Prof. Henryk Flashner (USC)	Spacecraft Attitude Control
Dr. Anthony Freeman (JPL)	Remote Sensing
Prof. Solomon Golomb (USC)	Communication Signal Design
Dr. Keith Goodfellow (Lockheed-Martin)	Advanced Spacecraft Propulsion

Program Faculty and Lecturers (cont.)

Dr. Troy D. Goodson (JPL)	Spacecraft Dynamics
Prof. Mike Gruntman (USC)	Spacecraft&Missions; Space Physics&Instrum.
Dr. Gerald Hintz (JPL)	Orbital Mechanics
Prof. Yan Jin (USC)	Design Theory and Methods
Prof. Darrell L. Judge (USC)	Space Science and Space Instrumentation
Dr. Andrew Ketsdever (AFRL)	Space Environment
Prof. Bart Kosko (USC)	Signal Processing and Neural-Fuzzy Systems
Dr. Michael Kezirian (Boeing)	Spacecraft Dynamics
Prof. Joseph A. Kunc (USC)	Plasmas/Gas Kinetics; Molec.&Rad. Processes
Dr. Johnny Kwok (JPL)	Orbital Mechanics
Prof. John McIntyre (USC&HSC, retired)	Spacecraft Dynamics
Prof. E. Phil Muntz (USC)	Hypersonic Flows and MEMS
Dr. Robert Parker (Northrop-Grumman)	Spacecraft Power Systems
Dr. Geraldine Peters (USC)	Astronomy and Astrophysics
Dr. G.P. Purohit (Boeing)	Spacecraft Thermal Control and Propulsion
Prof. Stan Settles (USC)	System Architecting and Engineering
Prof. Robin Shakeshaft (USC)	Atomic and Molecular Physics
Prof. Donald E. Shemansky (USC)	Planetary Science
Dr. Joseph Sullivan (USC-ISI)	Advanced Systems
Dr. Madhu Thangavelu (AAA Visioneering)	Space Architecting
Dr. Kent Tobiska (Space Environm. Techn.)	Space Environment
Prof. Firdaus E. Udwadia (USC)	Applied Mathematics and Mechanics
Dr. James Wertz (Microcosm)	Space Mission Design
Prof. Peter Will (USC-ISI)	Robotics and Space Assembly
Prof. Bingen Yang (USC)	Structural Dynamics

AFRL = Air Force Research Laboratory

HSC = Hughes Space and Communications

ISI = USC's Information Sciences Institute

JPL = Jet Propulsion Laboratory, NASA

Bachelor of Science in Astronautical Engineering

The USC Astronautics and Space Technology Division Offers the Degree of
Bachelor of Science in Astronautical Engineering

Curriculum

Freshman Year, fall

ASTE 101L
Introduction to Astronautics
MASC 110L, Chem 105aL, or Chem 115aL
Chemical Properties of Materials, or
General Chemistry, or Advanced General
Chemistry
Math 125
Calculus I
General Education Elective

Freshman Year, spring

AME 150L
Intro to Computational Methods in AME
Math 126
Calculus II
Phys 151L
Physics I: Mechanics & Thermodynamics
Writ 140
Writing and Critical Reasoning

Sophomore Year, fall

AME 201
Statics
Math 226
Calculus III
Phys 152L
Physics II: Electricity and Magnetism
General Education Elective

Sophomore Year, spring

AME 204
Strength of Materials
Math 245
Mathematics of Physics and Engineering I
Phys 153L
Physics III: Optics and Modern Physics
ASTE 280
Astronautics and Space Environment I
General Education Elective

Junior Year, fall

AME 301
Dynamics
ASTE 301a
Thermal and Statistical Systems I
AME 404
Comp. Solutions to Engineering Problems
AME 341aL
Mechoptronics Laboratory I
ASTE 330
Astronautics and Space Environment II

Junior Year, spring

AME 308
Computer-Aided Analysis for Aero-
Mechanical Design
ASTE 301b
Thermal and Statistical Systems II
AME 341bL
Mechoptronics Laboratory II
WRIT 340
Advanced Writing Course
General Education Elective

Senior Year, fall

AME 441aL
Senior Projects Laboratory
ASTE 470
Spacecraft Propulsion
3 Technical Electives

Senior Year, spring

ASTE 420
Spacecraft Design
ASTE 480
Spacecraft Dynamics
2 Technical Electives
General Education Elective

B. S. in Astronautical Engineering Course Descriptions

In addition to these specialized classes, all students take mathematics, physics, chemistry, and other classes required for engineering students.

Required Astronautics Courses

ASTE 101L Introduction to Astronautics

Gateway to the Astronautics area of emphasis. Introduction to space, space exploration and the space business. Elements of orbits, spacecraft systems, rocket propulsion, and communications. Laboratory: Introduction to graphics, computation and simulation.

ASTE 280 Astronautics and Space Environment I

Solar system. Two-body problem. Orbits. Hohmann transfer. Rocket equation. Space environment and its effects on space systems. Sun. Solar wind. Geomagnetic field. Atmosphere, ionosphere, magnetosphere.

ASTE 301a,b Thermal and Statistical Systems

Thermodynamics and statistical mechanics. Kinetics of atoms, molecules, and photons. Compressible fluid mechanics.

ASTE 330 Astronautics and Space Environment II

Basics of spacecraft dynamics. Euler's equation. Introduction to space plasma physics. Spacecraft in plasma. Radiation effects on space systems. Space instrumentation: detectors, analyzers, spectrometers.

ASTE 420 Spacecraft Design

Spacecraft mission design, space environment, attitude determination and control, telecommunication, propulsion, structures and mechanisms, thermal control, power systems, launch systems and facilities. Semester design project.

ASTE 470 Spacecraft Propulsion

Introduction to rocket engineering. Space missions and thrust requirements. Compressible gas dynamics. Propellant chemistry and thermodynamics. Liquid- and solid-fueled rockets. Nuclear and electric propulsion.

ASTE 480 Spacecraft Dynamics

Two-body motion. Rigid-body motion. Attitude dynamics and maneuvers. Spacecraft stabilization: gravity gradient, reaction wheels, magnetic torques. Thruster attitude control.

Microsatellite Project

The Microsatellite Project is a student group within the Astronautics and Space Technology Division (ASTD). Its purpose is to enable students to obtain hands-on experience with space hardware through designing, building, and launching small satellites and satellite components. The faculty advisor for the Project is Prof. Dan Erwin. Students participate in the project on a volunteer basis.

Recommended Technical Electives

ASTE 445 Molecular Gas Dynamics

ASTR 400 The Solar System

EE 464 Probability Theory for Engineers

AME 477 Solar System Exploration

Master of Science in Astronautical Engineering

The USC *Astronautics and Space Technology Division* Offers
the Degree of
Master of Science in *Astronautical Engineering*

Required Course Work

Minimum number of units - 27

Core Requirement - 6 units

ASTE 520 (3) Spacecraft System Design

ASTE 535 (3) Space Environments and Spacecraft Interactions

Core Elective Requirement - 3 units

Choose one 3-unit courses from the list of Astronautics core elective requirement classes (p.8)

Technical Elective Requirement - 12 units

Four 3-unit courses. It is advisable to select these four elective courses from the list of Astronautics core electives or Astronautics recommended electives (p.8). Other science and engineering classes can also be taken to satisfy the technical elective requirement (program approval required).

No more than three units of directed research (ASTE 590) can be applied to the 27-unit degree requirement.

Engineering Mathematics Requirement - 6 units

AME 525(3) and AME 526(3) - Engineering Analysis

At least 21 units must be at the 500 or 600 level

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- All School of Engineering general requirements for the Master of Science must be satisfied
 - A student may choose to write a Master's Thesis (credit 4 to 8 units)
 - All core requirement, core elective (except one course), and engineering mathematics requirement courses are available through USC Distance Education Network DEN (p.19).

M.S. in Astronautical Engineering Core, Core Elective, and Elective Courses

Astronautics Core Courses (Required):

- * ASTE 520 (3) -- Spacecraft System Design
- * ASTE 535 (3) -- Space Environments and Spacecraft Interaction

Astronautics Core Elective Courses:

- * ASTE 470 (3) – Spacecraft Propulsion
- * ASTE 523 (3) – Design of Low Cost Space Missions
- * ASTE 552 (3) – Spacecraft Thermal Control
- * ASTE 553 (3) – Systems for Remote Sensing from Space
- * ASTE 556 (3) – Spacecraft Structural Dynamics
- * ASTE 580 (3) – Orbital Mechanics I
- ASTE 581 (3) – Orbital Mechanics II
- * ASTE 583 (3) – Space Navigation: Principles and Practice
- * ASTE 584 (3) – Spacecraft Power Systems
- * ASTE 585 (3) – Spacecraft Attitude Control
- * ASTE 586 (3) – Spacecraft Attitude Dynamics

Astronautics Recommended Technical Elective Courses:

- ASTE 501a(3) – Physical Gas Dynamics I
- ASTE 501b(3) – Physical Gas Dynamics II
- ASTE 527 (3) – Space Studio Architecting
- ASTE 541 (3) – Partially Ionized Plasmas
- ASTE 545 (3) – Computational Techn. in Rarefied Gas Dynamics
- * ASTE 572 (3) – Advanced Spacecraft Propulsion
- * SAE 549 (3) – Systems Architecting I
- AME 511 (3) – Compressible Gas Dynamics
- * AME 513 (3) – Principles of Combustion
- AME 521 (3) – Engineering Vibrations II

In the future, we plan to offer courses in *Constellation Design*, *Manned Spaceflight*, *Space Communications*, *Advanced Chemical Propulsion*, *Space Science*, *Hypersonics*, and other space technology topics. Introduction of these new classes depends on availability of qualified instructors, distance education webcasting slots, and other programmatic factors.

Astronautics Engineering Mathematics Courses (Required):

- * AME 525(3) – Engineering Analysis
- * AME 526(3) – Engineering Analytical Methods

* Courses marked with * are available (webcast) through the USC Distance Education Network (DEN). See p.19.

The Astronautics and Space Technology Division does not require that classes be taken in any particular sequence, except that a class may only be taken after its prerequisites have been satisfied; check class descriptions in the USC Catalogue. The class sequence is established by students with the help of program faculty, if needed.

M. S. in Astronautical Engineering Admission Requirements

1. B.S. in Science or Engineering

In some cases the applicant may be required to take 1 or 2 deficiency courses (undergraduate classes, e.g., ASTE 470 Spacecraft Propulsion). The decision to require deficiency courses is made by the Astronautics Program coordinators.

Good news: the required deficiency 400-level courses can be applied for credit, as technical electives, toward the M.S. degree. Note that no more than two 400-level courses can be applied toward the M.S. degree.

2. Grade Point Average (GPA) – at least 3.0 (A ≡ 4.0)

3. GRE

The general portion of the Graduate Record Examination (GRE) is required

4. Recommendation Letters

Two recommendation letters, characterizing academic, professional, and personal qualities of the applicant, are required. Strong letters are particularly important for conditional admission.

In some cases, a student may be admitted to the program conditionally. A condition might be to maintain “grades of B or better in each course” or “average grade B or better” before the completion of 12 units of course work. The decision to admit a student conditionally is made by the Astronautics Program coordinators.

Limited status and non-degree option students

Please note that the School of Engineering allows enrollment as a limited status student (Astronautics and Space Technology Division permission is required) and as a non-degree option (NDO) student (Distance Education students only), without being formally accepted to a specific degree program. Not more than 12 units may be taken as a limited status student; only the first 12 units taken as an NDO student may be later applied for credit toward an advanced degree. This path is usually a convenient way to begin taking classes while the admission application is processed.

Astronautics Graduate Class Schedule

(subject to change – check with the Program Student Coordinator)

				2005	2006	2006	2007	2007	2008	2008	2009
				Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Core Requirement Courses											
ASTE 520	Spacecraft Design	1	D R		✓		✓		✓		✓
ASTE 535	Space Environment and Spacecraft Interactions	1	D R	✓		✓		✓		✓	
Elective Courses											
ASTE 470	Spacecraft Propulsion	1	D C	✓		✓		✓		✓	
ASTE 501a	Physical Gas Dynamics I	2	N C			✓				✓	
ASTE 501b	Physical Gas Dynamics II	2	N C				✓				✓
ASTE 523	Design of Low Cost Space Missions	2	D C				✓				✓
ASTE 527	Space Studio Architecting	1r	N E	✓							
ASTE 541	Partially Ionized Plasmas	1r	N E								
ASTE 545	Comput. Techniques in Rarefied Gas Dynamics	2	N E				✓				
ASTE 553	Systems for Remote Sensing From Space	2	D C	✓				✓			
ASTE 552	Spacecraft Thermal Cntrl.	2	D C		✓				✓		
ASTE 556	SC Structural Dynamics	2	D C			✓				✓	
ASTE 572	Advanced SC Propulsion	2	D E		✓				✓		
ASTE 580	Orbital Mechanics I	1	D C	✓		✓		✓		✓	
ASTE 581	Orbital Mechanics II	1r	N C								
ASTE 583	Space Navigation	2	D C		✓		✓		✓		✓
ASTE 584	SC Power Systems	2	D C				✓				✓
ASTE 585	SC Attitude Control	1r	D C								
ASTE 586	SC Attitude Dynamics	2	D C		✓				✓		
SAE 549	System Architecting	1	D E	✓	✓	✓	✓	✓	✓	✓	✓
AME 511	Compress. Gas Dynamics	1	N E		✓		✓		✓		✓
AME 513	Principles of Combustion	1	D E		✓		✓		✓		✓
AME 521	Engineering Vibrations II	1	N E	✓		✓				✓	
Mathematics Requirement											
AME 525	Engineering Analysis	1	D R	✓	✓	✓	✓	✓	✓	✓	✓
AME 526	Engineering Analyt. Meth.	1	D R	✓	✓	✓	✓	✓	✓	✓	✓

Legend: SC = spacecraft
 1 = class offered each year
 2 = class offered every second year
 1r = class offered irregularly (check with the student coordinator)
 R = required
 C = core elective
 E = technical elective
D = webcast through DEN
 N = not available through DEN

Core requirement and mathematics requirement courses are offered each year.

Many technical electives are offered every second year or irregularly.

We plan to offer new (additional) classes on space technology.

Check with the program student coordinator when planning the class sequence.

Astronautics Graduate Classes: Syllabi

Core Requirements

ASTE 520

Spacecraft System Design

1. History of space exploration.
2. Universe, galaxy, solar system. Plasma.
3. Space environment. Hardness.
4. Orbit design: basic orbits, perturbations, ΔV .
5. Space mission geometry; astrodynamics.
6. Spacecraft and mission design overview. Operations, infrastructure. Reliability.
7. Guidance, navigation and control; attitude determination; reaction control system. GPS.
8. Spacecraft propulsion.
9. Launch systems.
10. Communications.
11. TT & C; data handling.
12. Electric power systems.
13. Thermal control.
14. Structures and mechanisms.

ASTE 535

Space Environments and Spacecraft Interactions

1. Kinetic theory, atomic and molecular physics.
2. Solar physics, plasma physics.
3. Gas-surface interactions.
4. Vacuum environment – solar UV radiation, molecular components.
5. Neutral environment - atomic oxygen.
6. Plasma environment: ions, electrons, solar wind.
7. Radiation environment - high-energy particles and photons.
8. Outgassing, satellite drag, contamination.
9. Spacecraft ("Shuttle") glow, material degradation.
10. Spacecraft charging, discharging.
11. Sputtering, single event effects.
12. Ground based simulations of the space environment.

Mathematics Requirements

AME 525

Engineering Analysis

1. Finite dim. vector spaces and linear algebra. Basic concepts; eigenvalues and eigenvectors. Solving $Ax=b$: the Fredholm alternative. Least squares solutions.
2. Vector analysis; line integrals in space. Gauss' divergence theorem. Green's identities and multi-dimensional integration by parts. Stokes theorem.
3. Complex variables. Analytic functions; $w=f(z)$ as a mapping. Cauchy-Riemann equations. Harmonic functions.
4. Integrals of complex functions. Contour integrals: line integrals in the z -plane. Cauchy-Goursat theorem, Cauchy integral.
5. Residue theory. 2-D inviscid fluid flow and conformal mapping.

AME 526

Engineering Analytical Methods

1. Separation of variables. Sturm-Liouville problems. Special functions. Fourier series.
2. Second order linear theory. Introduction to heat, wave, Laplace equations. Diffusion equation; 1-D wave equation.
3. First order theory; characteristics. Quasi-linear equations; shocks.
4. Second order equations: hyperbolic. Random walks and Brownian motion. Cauchy problem; Cauchy-Kowaleski Theorem. Second order equations: elliptic fundamental solutions; Green's formula.
5. Gauss' theorem, mean value theorem. Dirichlet and Neumann problems. Eigenvalue problems. Laplace equation.
6. Rayleigh quotient. Courant's Max-Min principle. Rayleigh-Ritz method.

Core Technical Electives and Recommended Technical Electives

ASTE 470

Spacecraft Propulsion

1. History of rocketry. Types of rockets.
2. Solar system. Orbital mechanics. Hohmann transfer, maneuvers. Launching sites.
3. Thrust. Specific impulse. Rocket equation. Staging. Thermodynamics of fluid flow.
4. Combustion. Chemical equilibrium.
5. One-dimensional flow. Flow in nozzles. Non-ideal flow. Shocks. Boundary layer.
6. Ideal rocket, thrust coefficient, characteristic velocity. Nozzle types.
7. Rocket heat transfer.
8. Liquid rocket systems. Starting and ignition. Combustion. Injection. Liquid propellants.
9. Solid rocket. Burn rate, erosive burning. Grain design. Solid propellants.
10. Hybrid rockets. Thrust vector control.
11. Advanced propulsion. Power sources: chemical, solar, nuclear. Electrostatic, electrothermal, electromagnetic thrusters.

ASTE 501a

Physical Gas Dynamics I

1. Modern description of gas properties: microscopic vs. macroscopic approach; probability and statistical mathematics; phase spaces; classical vs. quantum approach.
2. Quantum mechanics: wave functions, structure of particles, translational, rotational, vibrational and electronic properties of molecules.
3. Statistical mechanics: models of equilibrium, statistical ensembles, distribution of particle energies, local thermodynamic equilibrium.
4. Molecular thermodynamics: molecular equation of state, entropy, internal energy, enthalpy, specific heats, Gibbs energy.

5. Forces between particles: multipoles; chemical bond; intermolecular potentials.

ASTE 501b

Physical Gas Dynamics II

1. Interaction of particles: elastic and inelastic collisions; cross sections and rate coefficients.
2. Gas kinetics: fluxes of particles and energy; the law of mass action; ionization and dissociation of gas; recombination of particles.
3. Plasmas: partially and fully ionized gas; Saha equation; interaction of waves with particles.
4. Transport properties: Boltzmann equation; conductivity, viscosity and diffusion coefficient, relaxation processes.
5. Radiative processes: blackbody radiation, radiative transfer equation, emission and absorption of radiation; distribution of photon energies; statistics of photons.

ASTE 523

Design of Low Cost Space Missions

1. Background – range of cost options, traditional vs. radical cost cutting methods.
2. Process changes to reduce cost - concurrent engineering, design-to-cost, schedule compression.
3. Technology for reduced cost – hardware, software, autonomy.
4. Reducing mission cost – spacecraft, launch, ground segment, operations.
5. Case studies – missions with successfully reduced cost.
6. Implementation strategies – cost-reduction programs, implementation problems, counterproductive approaches.
7. Design study.

ASTE 527 Space Studio Architecting

1. Architecting and programmatic for complex space missions.
2. The "wicked problem," "out of bounds" parameters.
3. Heuristics: inductive and analogous processes.
4. Global, top level space exploration and development architectures.
5. Alternative concepts creation: iterative design evolution.
6. Individual and team project.
7. Case study lectures by experts.
8. Faculty/NASA/Industry review and evaluation panel.

ASTE 545 Computational Techniques in Rarefied Gas Dynamics

1. Kinetics. Rarefaction. Distribution function. Sampling.
2. Boltzmann and N-S equations. Potentials. Collisions. Transport.
3. Scattering models. Relation of mean free path to cross section. Intro to Direct Simulation Monte Carlo (DSMC) computation. Molecular indexing.
4. Flux and averages in flowing gas. Distributions of entering and of colliding molecules. Grids. Molecular motion. Wall interactions.
5. Complete 1D DSMC. Shock structure.
6. 2D and axisymmetric grids. Indexing schemes. Weighting factors.
7. Inelastic collisions: rotation and vibration.
8. Chemistry. Reactive shock structure. Freezing.
9. Ionization. Plasma modeling. Introduction to particle-in-cell computation. Beams and waves.
10. Discrete-velocity methods. Cellular automata.

ASTE 541 Partially Ionized Plasmas

1. Laboratory and space plasmas.
2. Non-equilibrium, steady-state, and local thermodynamic equilibrium.
3. Forces between particles.
4. Collisional and radiative processes.
5. Distributions of charged particles.
6. Transport properties in plasmas.
7. Plasmas in electric and magnetic fields.

ASTE 552 Spacecraft Thermal Control

1. Requirements, basic principles, and applications of spacecraft thermal management and control.
2. Spacecraft thermal environments.
3. Thermal verification requirements.
4. Test facilities, and practices.
5. Basic heat transfer modes.
6. Insulation, radiators, fluid thermal control systems and heat pipes.

ASTE 553 Systems for Remote Sensing

1. Remote sensing overview. Orbital mechanics.
2. Nature and properties of electromagnetic waves.
3. Visible and near infrared remote sensing: surfaces.
4. Thermal infrared remote sensing.
5. Passive microwave remote sensing.
6. Real and synthetic aperture radars.
7. Altimeters and scatterometers.
8. Polarimetric and interferometric synthetic aperture radar.
9. Remote sensing of atmospheres.
10. Visible and near infrared remote sensing: atmospheres
11. Millimeter and submillimeter sensing of atmospheres.
12. Microwave remote sensing: atmospheres.

ASTE 556 Spacecraft Structural Dynamics

1. Introduction: Structural Dynamics, Spacecraft Design, & Analytical Tools
2. Vibration of Single and Multiple Degree of Freedom Systems
3. Infinite Degree of Freedom Systems
4. Strain Actuated Structures.
5. Structural Dynamics Modeling of Spacecraft
6. Analysis of spacecraft dynamics
7. Computation of Spacecraft Dynamic Loads
8. Dynamics Testing of Spacecraft

ASTE 572 Advanced Spacecraft Propulsion

1. Review of rocket fundamentals.
2. Basics of advanced propulsion.
3. Nuclear rockets.
4. Space power systems (nuclear and solar).
5. Fundamentals of electric propulsion: electromagnetics, ionization of gases, particle collisions, electrode effects.
6. Acceleration mechanisms: electro-thermal, electrostatic, electromagnetic.
7. Electric propulsion thrusters.
8. Electric propulsion systems: power, propellant, and control.
9. Advanced concepts: solar sails, beamed energy, fusion, lasers, antimatter.
10. Special applications: tethers, micro-propulsion, piloted Mars mission.

ASTE 580 Orbital Mechanics I

1. Physical principles.
2. Coordinate systems and transformations.
3. Two-body and central force motion.

4. Hill's equation; position and velocity formulas.
5. Lambert's problem and mission design.
6. Keplerian vs. Cartesian orbital elements.
7. Potential function for a distributed mass.
8. The n-body problem. Orbital perturbations.
9. Maneuver design techniques.
10. Rocket equation; satellite orbit paradox.

ASTE 581 Orbital Mechanics II

1. Non-spherical central body.
2. Luni-solar gravitational forces.
3. Drag and propulsion.
4. High-precision mathematical methods.
5. Station-keeping of geosynchronous satellites.
6. Sun-synchronous orbit design.
7. Gravity assist maneuvers.
8. Launch window design.
9. Planetary targeting techniques.

ASTE 583 Space Navigation: Principles and Practice

1. Navigating the solar system: an overview.
2. Required mathematical background; an overview of probability and statistics.
3. The orbit determination problem.
4. Error sources included in statistical analyses.
5. The (weighted) least squares solution; minimum variance and maximum likelihood solutions.
6. Computational algorithms for batch and sequential processing; state noise compensation; smoothing.
7. Square-root filter algorithms.
8. Elementary illustrative examples.

9. Consider covariance analyses.
10. Online ephemeris generation/3D visualization for Potentially Hazardous (earth-approaching) Asteroids.
11. Launch considerations; rocket payloads and staging; launch vehicles and sites.
12. Space navigation principles and practice – trajectory optimization, orbit estimation (radiometric and optical navigation), and flight path control.

ASTE 584 **Spacecraft Power Systems**

1. Requirements and environment.
2. Solar cells: silicon, gallium arsenide.
3. Solar arrays.
4. Batteries: nickel hydrogen; nickel cadmium.
5. Power electronics.
6. Harness. Dynamics. Reliability.
7. Power system design topologies.
8. Emerging technologies.

ASTE 585 **Attitude Control of Spacecraft**

1. Spacecraft dynamics and kinematics: Euler moment equations; rotational motion of a spinning body; dissipation effects; spacecraft attitude dynamics; actuators and sensors.
2. Review of control theory: transfer functions; frequency response; stability; state space representation.
3. Gravity-gradient stabilization: basic attitude control equation; gravity gradient attitude control with passive and active damping.
4. Magnetic attitude control.
5. Attitude maneuvers.
6. Momentum-based attitude control: stabilization with and without active control.
7. Reaction thruster attitude control.

ASTE 586 **Spacecraft Attitude Dynamics**

1. Mathematical preliminaries.
2. Kinematics and dynamics.
3. Stability of motion.
4. Spinning spacecraft.
5. Lagrangian and Hamiltonian mechanics
6. Dual spin spacecraft.
7. Environmental and disturbance torques.
8. Gravity gradient spacecraft.
9. Momentum bias spacecraft.

SAE 549 **Systems Architecting I**

1. System concepts.
2. The system architecting process.
3. Requirements generation.
4. Boundaries and interfaces.
5. Modeling, simulation, and prototyping.
6. Architecting tools.
7. Building systems.
8. System test, acceptance, and operations.
9. Case studies.

AME 511 **Compressible Gas Dynamics**

1. Compressible flow equations.
2. One-dimensional and quasi-one-dimensional flows.
3. Shocks and expansion waves.
4. Unsteady wave motion.
5. Linearized flow.
6. Numerical techniques for supersonic flow.
7. Three-dimensional flow.
8. Transonic flow.
9. Hypersonic flow.
10. High-temperature flows.

AME 513
Principles of Combustion

1. Thermodynamics of pure substances and mixtures.
2. Chemical kinetics & combustion chemistry.
3. Transport phenomena: simplified and rigorous derivation of transport coefficients.
4. Conservation equations for multi-component reacting flows.
5. Theory of non-premixed flames.
6. Theory of premixed flames.
7. Aerodynamics of laminar flames.
8. Fundamentals of chemical propulsion: physics and chemistry of liquid and solid propellants, combustion instabilities.
9. Introduction to numerical simulations of multi-component reacting flows.
10. Experimental methods for high-temperature, multi-component reacting flows.

Engineer Degree in Astronautical Engineering

**The USC *Astronautics and Space Technology Division*
Offers
the *Engineer Degree in Astronautical Engineering***

Admission Requirements:

- 1. General admission requirements for the Engineer Degree of the School of Engineering**
- 2. Admission requirements for the M.S. Degree in Astronautical Engineering (see p.9)**

Check for the details with the Engineer Degree Program Coordinator

Doctor of Philosophy in Astronautical Engineering

**The USC *Astronautics and Space Technology Division* Offers
the Ph.D. Degree in *Astronautical Engineering***

Admission Requirements:

- 1. General requirements for the Ph.D. Degree of the School of Engineering**
- 2. B.S. or M.S. in science or engineering**

If some cases one or more undergraduate courses may be required to prepare for the graduate coursework.

- 2. Grade Point Average (GPA)** – at least 3.5 (A≅4.0)

- 3. GRE**

The general portion of the Graduate Record Examination (GRE) is required

- 4. Recommendation Letters**

Three recommendation letters, characterizing academic, professional, and personal qualities of the applicant, are required.

Check for details with the Ph.D. Degree Program Coordinator

Certificate in Aerospace Engineering (Astronautics)

The USC *Astronautics and Space Technology Division* Offers the Certificate *in Aerospace Engineering (Astronautics)*

The Program is designed for practicing engineers and scientists who enter space-related fields and/or who want to obtain training in specific space-related areas. The students can enroll at USC as limited status students and have to apply and be admitted to the certificate Program not later than completion of 9 units of the required coursework. A special Certificate is issued after completion of the coursework.

<u>Required Course Work</u>	–	12 units (choose four 3-unit courses):
* ASTE 520 (3)	--	Spacecraft System Design
* ASTE 535 (3)	--	Space Environments and Spacecraft Interaction
* ASTE 523 (3)	–	Design of Low Cost Space Missions
* ASTE 552 (3)	–	Spacecraft Thermal Control
* ASTE 553 (3)	–	Systems for Remote Sensing from Space
* ASTE 556 (3)	–	Spacecraft Structural Dynamics
* ASTE 580 (3)	–	Orbital Mechanics I
ASTE 581 (3)	–	Orbital Mechanics II
* ASTE 583 (3)	–	Space Navigation: Principles and Practice
* ASTE 584 (3)	–	Spacecraft Power Systems
* ASTE 585 (3)	–	Spacecraft Attitude Control
* ASTE 586 (3)	–	Spacecraft Attitude Dynamics
* ASTE 572 (3)	–	Advanced Spacecraft Propulsion

For class schedule, please consult p. 11.

Admission Requirements:

1. B.S. in Engineering or Science
2. GPA - 3.00

Distance Education Network

- * Courses marked with * are available (televised and webcast) through the USC Distance Education Network (DEN). See p.19.

Credit

Credit for classes may be applied toward the M.S. or Ph.D. in Astronautical Engineering should the student decide later to pursue an advanced degree. In order to be admitted to the M.S. Program the student should maintain a B average or higher in courses for the Certificate and must satisfy all normal admission requirements. All courses for the Certificate must be taken at USC.

Astronautics and Space Technology

Distance Education

USC Distance Education Network (DEN)

Established in 1972, the USC Distance Education Network (DEN) is an extensive, interactive one-way video, two-way audio e-learning system that enables full-time professional engineers to take USC School of Engineering courses for graduate degree credit from the convenience of their company facilities or homes.

Regular campus classes are webcast (Internet-accessible), making them available to students for USC graduate credit and auditing, practically anywhere in the United States.

The DEN web site – <http://den.usc.edu> - provides extensive program and contact information.

Astronautics Program via Distance Learning

Employees of companies affiliated with USC DEN can obtain the degrees of **Master of Science in Astronautical Engineering** and **Certificate in Aerospace Engineering (Astronautics)** from remote locations. In addition, DEN can accommodate the independent student; this latter category is rapidly growing. All required and core elective classes and many elective classes are webcast. Thus, Astronautics students taking classes via DEN have an excellent choice of space technology courses.

DEN Company Affiliates (the list is growing – check with DEN for update)

Aerojet	NASA — Johnson Space Center
Aerospace Corp.	NASA — Kennedy Space Center
The Boeing Company	Northrop Grumman
The CATE Center	Odetics
Department of Water and Power	OralScan Laboratories Inc.
Ericsson Wireless Communications, Inc.	Orange County Regional Classroom
General Dynamics	Qualcomm Inc.
Intel Corporation	Raytheon
ITT/Gilfillan	SAIC
Lockheed Martin	Spectrum Astro, Inc.
Motorola	United Technologies (UTC)
NASA — Ames Research Center	Volt Delta Resources
NASA — Dryden Flight Research Center	Xerox Corp.
NASA — Jet Propulsion Laboratory	

Independent students

Students may enroll in DEN programs on their own, rather than through a DEN affiliate. Such independent students may reside anywhere in the United States.

University of Southern California

Astronautics and Space Technology

B.Sc., M.Sc., Engineer, and Ph.D. Degrees and Certificate

Application

You have decided to apply to a program offered by the Astronautics and Space Technology Division. What's next?

1. **Read this brochure**
2. **Look at the Program web site at <http://astronautics.usc.edu> for the program updates and frequently asked questions.**
3. **An application is available on-line at <http://www.usc.edu/dept/admissions/grad>.**
4. **Contact the Astronautics Program Student Coordinator**
telephone: 213-821-5817
e-mail: astd@usc.edu
for additional information. The Astronautics Program Student Coordinator is your contact regarding all questions related to the application procedure, paperwork, etc.
4. **If needed, contact the appropriate Astronautics Program Faculty Coordinator (see p.3) with questions regarding class selection, program focus, etc.**
e-mail: info@astronautics.usc.edu

Good Luck!

Per Aspera Ad Astra!