



ASTE 520

Spacecraft Design

Fall 2023

Mike Gruntman

**Department of Astronautical Engineering
Viterbi School of Engineering
University of Southern California
Los Angeles**

Spacecraft Design, Fall 2023
(set of notes on spacecraft design)
Mike Gruntman, 2023

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ASTE 520 *Spacecraft System Design*



Required for *Astronautical Engineering*

Regardless of your engineering or science major (electrical, mechanical, aerospace, systems, computer, etc. or physics, astronomy, chemistry, math, etc.) and regardless of your **job function** (research, development, design, test, manufacturing, management, marketing, etc.)

If you work or plan/desire to work in the space/defense industry or government space R&D centers or in space operations, then ...
this is a course (on space systems) that you must take.

ASTE520 focuses on the fundamentals of space systems. It will help you put into perspective your area of specialization and enable professional communications with other subsystem specialists.

This popular course is among the largest graduate space systems and space technology courses in the United States, with 2300 students enrolled since 1994.

Academic year 2023–2024

ASTE520 Spacecraft Systems Design is offered
only in the fall (2023) semester (not offered in Spring 2024).

Fall 2023 Thursday, 6:40 – 9:20 pm (Pacific Time)

Class enrollment is unlimited

For students enrolled in the class:

Course materials for *ASTE 520* will be posted on the DEN class website in mid-August.

Help with access the D2L site <http://courses.uscdcn.net> at DEN:
<http://gapp.usc.edu/graduate-programs/den/students>

ASTE-520 public web site (<http://astronauticsnow.com/aste520/>)
provides information on the syllabus, textbooks, and much more.

Spacecraft Design – ASTE 520

Thursday, 6:40–9:20 p.m., OHE-100D

Fall 2023

Class	Date	Subject	NS	W&E&P New SMAD (L&W SMAD); [FSM] Chapters	HW Due
1	Aug 24	Organization of the class. History of rocketry and space (<i>self study</i>). Universe, galaxy, solar system.	0 1 2	1 [1,2]	
2	Aug 31	Space environment.	3	7 (8) [3]	1,2
3	Sep 07	Orbital mechanics.	4	9 (5,6,7) [4-8]	3,4,5
4	Sep 14	Orbital mechanics. Space mission geometry.	4 5	8,9 (5,6,7) [5-8] 8,9 (5,6,7) [9]	6, 7, 8
5	Sep 21	Space mission geometry. Attitude determination and control (ADC).	5 7	8 (5) [9] 19 (10,11) [3]	9,10,11
6	Sep 28	Attitude determination and control (ADC).	7	19 (10,11) [3]	12,13,14,15
7	Oct 05	Spacecraft Propulsion.	8	18 (17,18)	16,17,18
Fall recess	Fall recess	Spacecraft and mission design overview. Facilities. Operations. Reliability <i>watch lecture NS-6; no HW; 2-day recess</i>	6	1,3,4,6,14,24,28,29 (1,3,4,10,14,15,19)	
8	Oct 19	MID-TERM	7:00–9:00 p.m. (Pacific)		
9	Oct 26	Launch systems. Communications	9 10	26,27 (17,18) 16,21 (10,11,13)	19,20
10	Nov 02	Communications	10	16,21 (10,11,13,16)	21,22
11	Nov 09	Electric Power systems.	11	21 (10,11)	23,24,25
12	Nov 16	Thermal control.	12	22 (10,11)	26,27
13	Nov 30	Structures and mechanisms	13	22 (10,11)	28,29,30
	Dec 07	FINAL EXAM	7:00–8:30 p.m. (Pacific)		

W&E&P New SMAD = Wertz, Everett, Puschell, The New SMAD
FSM = Gruntman, Fundamentals of Space Missions

L&W SMAD = Larson and Wertz, SMAD

NS = Notes Section; HW = homework

ASTE 520**Spacecraft Design****Notes****Contents****Section 0, Part 1 and Part 2
Organization of the Class**

- ⇒ syllabus
- ⇒ contents
- ⇒ organization of the class
- ⇒ homework, exams, grading
- ⇒ books, WWWeb resources
- ⇒ survey

**Section HW
Home Work problems****Section 01
Brief History****Section 02
Universe, Galaxy, solar system**

- ⇒ Universe
- ⇒ Galaxy
- ⇒ solar system
- ⇒ planets
- ⇒ coordinate systems
- ⇒ time

**Section 03
Space environment**

- ⇒ Sun
- ⇒ solar cycle
- ⇒ plasma
- ⇒ solar wind
- ⇒ Earth's magnetic field
- ⇒ atmosphere
- ⇒ ionosphere
- ⇒ magnetosphere
- ⇒ The "Big One" geomagnetic storm

- ⇒ spacecraft distribution at LEO and GEO
- ⇒ atmospheric drag
- ⇒ atomic oxygen
- ⇒ spacecraft charging
- ⇒ trapped radiation
- ⇒ radiation shielding
- ⇒ South Atlantic Anomaly
- ⇒ cosmic rays
- ⇒ micrometeoroids and debris

**Section 04
Orbital Mechanics**

- ⇒ motion in gravitational field
- ⇒ two-body approximation
- ⇒ elliptical orbit
- ⇒ circular and escape velocities
- ⇒ classical orbital elements
- ⇒ hyperbolic excess velocity
- ⇒ orbital transfers
- ⇒ Hohmann transfer
- ⇒ orbit plane change
- ⇒ rocket launch
- ⇒ launch sites
- ⇒ transfer to geostationary orbit
- ⇒ gravity-assist maneuvers
- ⇒ orbit perturbations
- ⇒ sun-synchronous orbit
- ⇒ Molniya orbit
- ⇒ eclipses
- ⇒ geosynchronous orbit
- ⇒ Hill's equations
- ⇒ libration points

Section 05**Mission geometry**

- ⇒ coordinate systems
- ⇒ satellite horizon
- ⇒ swath
- ⇒ satellite ground track
- ⇒ coverage, repeating orbits
- ⇒ satellite constellations

Section 06**Spacecraft and Mission Design****Overview. Operations. Reliability**

- ⇒ space missions
- ⇒ national security space
- ⇒ mission life cycle
- ⇒ reviews
- ⇒ mission design and planning
- ⇒ flowdown of requirements
- ⇒ technology readiness levels (TRL)
- ⇒ system engineering
- ⇒ learning from mistakes
- ⇒ science payloads
- ⇒ ground stations
- ⇒ Deep Space Network (DSN)
- ⇒ STDN, SGLS, SLR
- ⇒ TDRSS
- ⇒ reliability
- ⇒ mean time between failures (MTBF)
- ⇒ failure rates

Section 07**Spacecraft Attitude Determination and Control**

- ⇒ ADCS
- ⇒ configuration constraints

- ⇒ control loop
- ⇒ attitude representation
- ⇒ disturbance torques
- ⇒ magnetic torques
- ⇒ gravity gradient / stability
- ⇒ aerodynamic torques
- ⇒ solar radiation torques
- ⇒ attitude measurements
- ⇒ magnetometers
- ⇒ sun sensors
- ⇒ horizon sensors
- ⇒ star sensors
- ⇒ inertial-measurement units (IMU)
- ⇒ gyroscopes (rate, integrating, laser)
- ⇒ angular momentum
- ⇒ nutation damping
- ⇒ spacecraft attitude control configurations (spin, reaction wheels,)
- ⇒ stability of spinners
- ⇒ examples of problems (bang-bang, precession control)
- ⇒ reaction/momentum wheel
- ⇒ example of problems (reaction/momentum wheels)
- ⇒ Global Positioning System (GPS)

Section 08**Spacecraft Propulsion**

- ⇒ propulsion requirements
- ⇒ rocket classification
- ⇒ thrust, specific impulse, total impulse
- ⇒ rocket equation
- ⇒ multistaging

- ⇒ flow parameters in the nozzles
- ⇒ nozzles and diffusers
- ⇒ thrust coefficient, characteristic velocity
- ⇒ nozzles
- ⇒ rocket heat transfer and cooling
- ⇒ propellant feed systems
- ⇒ propellant tanks
- ⇒ propellant expulsion
- ⇒ liquid propellants
- ⇒ monopropellants and monopropellant thrusters
- ⇒ gelled propellants
- ⇒ solid rockets
- ⇒ grains
- ⇒ thrust vector control
- ⇒ electric propulsion
- ⇒ electrostatic thrusters
- ⇒ field emission electric propulsion (FEEP) and colloid thrusters
- ⇒ resistojet
- ⇒ arcjet
- ⇒ magnetoplasmadynamic thrusters (MPD)

Section 09 Launch Systems

- ⇒ launch issues
- ⇒ selection process
- ⇒ Atlas family
- ⇒ Delta family)

Section 10 Communications

- ⇒ frequency bands
- ⇒ evolution of communications satellites
- ⇒ communications architecture
- ⇒ constraints on spacecraft systems
- ⇒ decibel language
- ⇒ electromagnetic waves
- ⇒ EIRP
- ⇒ antenna gain
- ⇒ antennas
- ⇒ beam patterns
- ⇒ polarization loss
- ⇒ digital vs. analog
- ⇒ Nyquist's and Carson's rules
- ⇒ sampling and digitization
- ⇒ data rate
- ⇒ Shannon's Law
- ⇒ origins of noise
- ⇒ noise figure
- ⇒ link design
- ⇒ effect of atmosphere, rain, snow
- ⇒ modulation
- ⇒ encoding
- ⇒ BER
- ⇒ multiplexing
- ⇒ multiple access techniques
- ⇒ data compression
- ⇒ telemetry functions
- ⇒ transponder
- ⇒ telemetry data formats
- ⇒ data handling
- ⇒ ground data systems
- ⇒ space computer systems

Section 11

Electric Power Systems

- ⇒ requirements
- ⇒ classification
- ⇒ subsystem elements
- ⇒ design drivers
- ⇒ orbital effects
- ⇒ bus voltage
- ⇒ solar cells
- ⇒ solar arrays
- ⇒ batteries
- ⇒ nickel-cadmium batteries
- ⇒ nickel-hydrogen batteries
- ⇒ power processing

Section 12

Thermal Control

- ⇒ thermal control problems
- ⇒ environmental loads
- ⇒ blackbody concept
- ⇒ Planck and Stefan-Boltzmann Laws
- ⇒ thermal control components
- ⇒ coatings
- ⇒ multilayer insulation (MLI)
- ⇒ heaters
- ⇒ louvers
- ⇒ heat pipes
- ⇒ radiators
- ⇒ thermal analysis
- ⇒ thermal testing

Section 13

Structures and Mechanisms

- ⇒ purposes
- ⇒ sources of structural loads
- ⇒ launch
- ⇒ acoustic environment
- ⇒ basics of mechanics of materials
- ⇒ flexible-body dynamics
- ⇒ finite-element analysis
- ⇒ materials
- ⇒ primary structure
- ⇒ examples
- ⇒ spacecraft weight estimate
- ⇒ tests and simulations

ASTE 520**Spacecraft Design****Fall 2023****Home Work Schedule**

Problem	due date
1	31/08/2023
2	31/08/2023
3	09/07/2023
4	09/07/2023
5	09/07/2023
6	09/14/2023
7	09/14/2023
8	09/14/2023
9	09/21/2023
10	09/21/2023
11	09/21/2023
12	09/28/2023
13	09/28/2023
14	09/28/2023
15	09/28/2023
16	10/05/23
17	10/05/23
18	10/05/23
no HW – fall recess	10/12/23
no HW – midterm exam	10/19/2023
19	10/26/2023
20	10/26/2023
21	11/02/2023
22	11/02/2023
23	11/09/2023
24	11/09/2023
25	11/09/2023
26	11/16/2023
27	11/16/2023
28	11/30/2023
29	11/30/2023
30	11/30/2023

Homework must be submitted by 6:00 p.m. (Pacific time) on Thursday

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Mike Gruntman was graduated (M.Sc.) from the Department of Aerophysics and Space Research of the Moscow Physical-Technical Institute in 1977 and received his Ph.D. in physics from the Space Research Institute (IKI) of the USSR Academy of Sciences in 1984. He received specialized training in servicing liquid rocket engines.

Dr. Gruntman actively worked on the development of space technology, in particular novel instrumentation for laboratory and space applications, and conducted research in experimental and space physics. He has been especially active in the development of imaging photon-counting detectors for ground and space telescopes. Gruntman excelled in the study of the neutral components of space plasmas and developed new instrumentation for the detection of energetic neutral atoms. He was a visiting scientist at the FOM-Institute for Atomic and Molecular Physics in Amsterdam.

In March 1990, Gruntman joined the University of Southern California (USC), where he initially worked on reduction and evaluation of the data from Pioneer 10/11 spacecraft and actively participated in sounding rocket and space instrument development programs. He worked on the sounding rocket payload integration and testing at White Sands Missile Range.

Dr. Gruntman is Professor of Astronautics at USC since 1993. (He is also Professor of Aerospace Engineering and Professor of System Architecture Engineering.) He was/is Principal Investigator and Co-Investigator in theoretical and experimental programs funded by NASA and Air Force; he is Co-Investigator on current NASA missions TWINS and IBEX. His interests include astronautics, space mission and spacecraft design, satellite technologies, rocket and spacecraft propulsion, space sensors and instrumentation, local interstellar medium, heliospheric and magnetospheric physics, space plasmas and environment, particle and photon analyzers and detector systems, ion and neutral particle beams, atomic collisions, and particle interactions with surfaces.

Dr. Gruntman authored and co-authored 300+ scholarly publications, including six books, in various fields of astronautics, space technology, space physics, space and laboratory sensors and instrumentation, history of rocketry, spacecraft, and missile defense, and space education. He presented the results of his research at numerous international and national scientific and technological conferences and symposia and at scientific seminars at leading American and foreign research institutions and universities.

Prof. Gruntman taught/teaches courses in astronautics, spacecraft design, spacecraft propulsion, and space sciences. He also teaches short courses on space technology for government and industry.

Prof. Gruntman is the founder of the USC Astronautics Program that today offers BS, BS Minor, MS, Engineer, and PhD degrees and Graduate Certificate in Astronautical Engineering. In August 2004, Dr. Mike Gruntman was appointed the first (founding) Chairman (2004–2007) of the new space-engineering-focused (unique for American universities) academic unit in the USC Viterbi School of Engineering, today's Department of Astronautical Engineering (ASTE). He again served as the department chairman from 2016-2019.

Gruntman is Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and he served as Vice Chair (elected) for Education of the Los Angeles Section of AIAA from 1996–1998. He is Member (elected Academician) of the International Academy of Astronautics (IAA). Dr. Gruntman is also a member of the American Physical Society (APS) and American Geophysical Union (AGU).

Gruntman is a recipient of NASA's Group Achievement Awards (2000, 2001, 2011) and the USC School of Engineering Exceptional Service Award (1999). He served (elected) on the USC Engineering Faculty Council in 1996–1998, 1998–2000, 2008–2010, 2011–2012, 2014–2016, 2020-2022. In 2006, his AIAA-published book on history of rocketry and spacecraft received an award from the International Academy of Astronautics.

Mike served (2001–2003) on the editorial board of the world-leading journal on experimental techniques and scientific instrumentation, the *Review of Scientific Instruments*. He reviews manuscripts for several scientific journals, book publishers, and NASA. He organized (convened) sessions at major scientific conferences (AGU, COSPAR). Dr. Gruntman served/serves on advisory panels on science and technology programs at NASA Headquarters, NASA centers, and other government agencies.

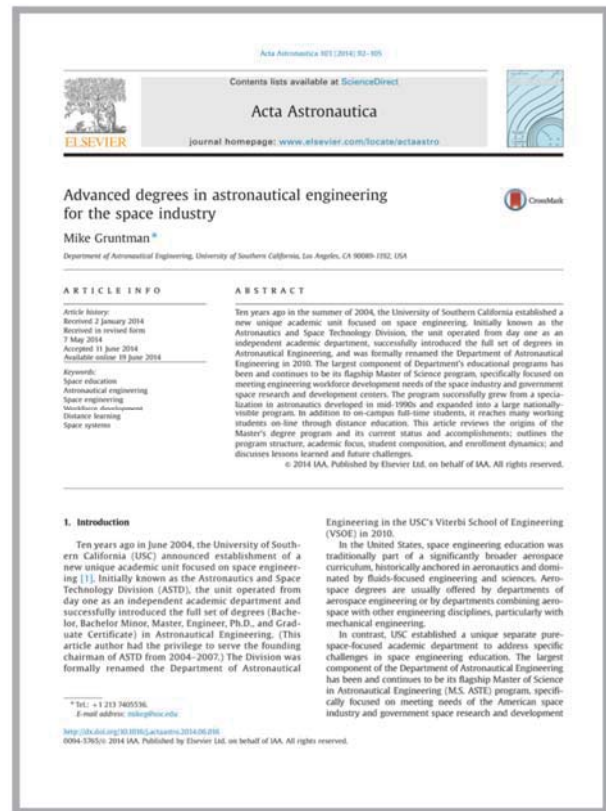
USC Astronautics program history, focus, rationale, and organization

Article in

Acta Astronautica
v. 103, 92–105, 2014

Abstract

Ten years ago in the summer of 2004, the University of Southern California established a new unique academic unit focused on space engineering. Initially known as the Astronautics and Space Technology Division, the unit operated from day one as an independent academic department, successfully introduced the full set of degrees in Astronautical Engineering, and was formally renamed the Department of Astronautical Engineering in 2010. The largest component of Department's educational programs has been and continues to be its flagship Master of Science program, specifically focused on meeting engineering workforce development needs of the space industry and government space research and development centers. The program successfully grew from a specialization in astronautics developed in the mid-1990s and expanded into a large nationally-visible program. In addition to on-campus full-time students, it reaches many working students online through distance education. This article reviews the origins of the Master's degree program and its current status and accomplishments; outlines the program structure, academic focus, student composition, and enrollment dynamics; and discusses lessons learned and future challenges.



Article download

<http://astronauticsnow.com/2014aste.pdf>

Article about the Master's ASTE degree online (DEN)

<http://astronauticsnow.com/2018aste.pdf>

Admission Requirements for Graduate Degrees in *Astronautical Engineering* – Code ASTE

The Department of Astronautical Engineering (ASTE) of the USC Viterbi School of Engineering offers degrees in **astronautical engineering**, code **ASTE**. The admission to MS ASTE is based on the totality of the applicant's record which includes GPA, GRE, and two letters of recommendation.

Required items:

Application
Official Transcript(s)
General Record Exam
TOEFL (international students only)
Recommendation Letters

Send To

Office of Grad. and Int'l Admission
 Office of Grad. and Int'l Admission
 Office of Grad. and Int'l Admission
 Office of Grad. and Int'l Admission
 Office of Grad. and Int'l Admission

Application

All applications should be submitted online at <http://www.usc.edu/admission/graduate/apply/>

Official Transcript(s)

The University requires official transcripts from the accredited colleges or universities the applicant has attended. The MS Degree Program in Astronautical Engineering (Code ASTE) requires a minimum GPA of 3.0.

General Record Exam

The Department of Astronautical Engineering requires the general GRE. The GRE must be taken within five years of the application date. USC's ETS school code is 4852. Applicants taking the GRE should use this code to ensure official submission of test scores.

English Language Proficiency for International Applicants

In addition to the general admission criteria listed above, international students whose first language is not English are required to take the TOEFL or IELTS examination to be considered a candidate for admission. There is no minimum TOEFL or IELTS score required for admission to the Viterbi School. For possible exemption from additional language requirements, you must achieve an Internet Based TOEFL (iBT) score of 90, with no less than 20 on each section or an IELTS score of 6.5, with no less than 6 on each band score.

For more details on English Proficiency Criteria for the University of Southern California, please visit <https://www.usc.edu/admission/graduate/international/englishproficiency.html>.

Recommendation Letters

Please provide two professional letters of reference (former instructors, supervisors, professional colleagues, advisors, etc.) to be filed through the online application process.

Mailing addresses, if needed

Office of Graduate and International Admission
 University of Southern California, Los Angeles, CA 90089-0911

Department of Astronautical Engineering
 ASTE Graduate Program, 854 W. Downey Way
 University of Southern California, Los Angeles, CA 90089-1192

Application deadline: 15 June for fall; 1 October for spring; 1 February for summer.

Please note that verification and processing of materials by the Office of Graduate and International Admission may take four to six weeks.

Transfer to Astronautics Program and other Questions:

Please contact ASTE Senior Administrator Ms. Dell Cuason (RRB-225; tel. 213-821-5817; cuason@usc.edu) and visit <http://astronautics.usc.edu>.

Department of Astronautical Engineering (ASTE)

Student Transfer to Degrees in Astronautical Engineering (code ASTE)

Transfer Process – Viterbi Engineering Students

Please refer to VSOE change of major form and contact ASTE Student Services Director Mr. Luis Saballos (RRB-223; tel. 213-821-4234; saballos@usc.edu) for further details of the process.

Transfer Process – Non-Engineering Students

Transfer to a program in Astronautical Engineering, Code ASTE, requires a non-engineering student to file the USC application for graduate admission to the program in Astronautical Engineering. Processing of the application does not require re-submission of supporting documents (e.g., transcripts) that have been previously submitted to USC. Check with ASTE Student Services Director Mr. Luis Saballos (RRB-223; tel. 213-821-4234; saballos@usc.edu).

Restrictions

Transfer to a program in Astronautical Engineering, Code ASTE, cannot be requested during the first semester of student studies at USC.

Questions?

Please contact ASTE Senior Administrator Ms. Dell Cuason (RRB-225; tel. 213-821-5817; cuason@usc.edu).

More information on MS ASTE – <http://astronauticsnow.com/msaste/>

Frequently asked questions – <http://astronauticsnow.com/msaste/faq.html>

Integrity

Academic integrity of all students participating in this course is of fundamental importance for this instructor and is one of the most important components of the University rules and regulations. Students who violate University standards of academic integrity are subject to disciplinary sanctions, including failure in the course and suspension from the University. Since dishonesty in any form harms the individual, other students, and the University, policies on academic integrity will be strictly enforced. I expect you will familiarize yourself with Section 11, *Behavior Violating University Standards* in *SCampus*.

HomeWork, Exams, etc. are individual efforts

Academic Conduct

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* <https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/>. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct/>.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* <http://equity.usc.edu/> or the *Department of Public Safety* <http://capsnet.usc.edu/departments/departments-public-safety/online-forms/contact-us>.

This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* <http://www.usc.edu/student-affairs/cwm/> provides 24/7 confidential support, and the sexual assault resource center webpage sarc@usc.edu describes reporting options and other resources.

Support Systems

A number of USC’s schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* <http://dornsife.usc.edu/ali>, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* <http://emergency.usc.edu/> will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.

Some Useful Math (1/4)

Taylor's theorem

Let $f(x)$ be analytic at a . Then

$$f(x) = f(a) + f'(a) \frac{(x-a)}{1!} + f''(a) \frac{(x-a)^2}{2!} + f'''(a) \frac{(x-a)^3}{3!} + \dots + f^{(n)}(a) \frac{(x-a)^n}{n!} + \dots$$

An alternative form

$$f(a+h) = f(a) + f'(a) \frac{h}{1!} + f''(a) \frac{h^2}{2!} + f'''(a) \frac{h^3}{3!} + \dots + f^{(n)}(a) \frac{h^n}{n!} + \dots$$

Maclaurin's series: the special case when $a = 0$

$$f(x) = f(0) + f'(0) \frac{x}{1!} + f''(0) \frac{x^2}{2!} + f'''(0) \frac{x^3}{3!} + \dots + f^{(n)}(0) \frac{x^n}{n!} + \dots$$

Examples (elementary functions):

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!} x^2 + \frac{n(n-1)(n-2)}{3!} x^3 + \dots + \frac{n!}{(n-k)! k!} x^k + \dots, \quad |x| < 1$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

$$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots, \quad |x| \leq 1$$

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

$$\tan x = (\operatorname{tg} x) = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \frac{62x^9}{2835} + \dots, \quad |x| \leq \frac{\pi}{2}$$

$$\sec x \equiv \frac{1}{\cos x} = 1 + \frac{x^2}{2!} + \frac{5x^4}{4!} + \frac{61x^6}{6!} + \frac{1385x^8}{8!} + \dots, \quad |x| < \frac{\pi}{2}$$

$$\sin^{-1} x = (\arcsin x) = x + \frac{x^3}{6} + \frac{1 \cdot 3}{2 \cdot 4} \frac{x^5}{5} + \frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6} \frac{x^7}{7} + \dots, \quad |x| < 1$$

$$\tan^{-1} x = (\arctan x) = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \dots, \quad |x| < 1$$

Some Useful Math (2/4)

Indefinite integral of functions $\int dF(x) = F(x) + C$

Integration by parts $\int u dv = u v - \int v du$

Change of variables

Consider two sets of coordinates, or variables, (x, y, z) and (u, v, w) such that $x = x(u, v, w)$, $y = y(u, v, w)$, and $z = z(u, v, w)$. As an example, think about (u, v, w) being a set of spherical coordinates (R, θ, ϕ) . Then the function $F(x, y, z)$ would be

$$F(x, y, z) = F[x(u, v, w), y(u, v, w), z(u, v, w)] = G(u, v, w)$$

and

$$\iiint F(x, y, z) dx dy dz = \iiint G(u, v, w) \frac{\partial(x, y, z)}{\partial(u, v, w)} du dv dw$$

where the Jacobian determinant is

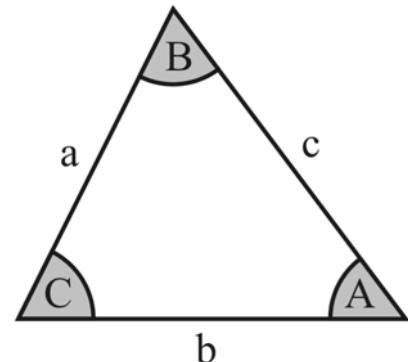
$$\frac{\partial(x, y, z)}{\partial(u, v, w)} = \begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial y}{\partial u} & \frac{\partial z}{\partial u} \\ \frac{\partial x}{\partial v} & \frac{\partial y}{\partial v} & \frac{\partial z}{\partial v} \\ \frac{\partial x}{\partial w} & \frac{\partial y}{\partial w} & \frac{\partial z}{\partial w} \end{vmatrix}$$

Plane oblique triangle

$$A + B + C = \pi = 180^\circ$$

Law of sines: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

Law of cosines: $c^2 = a^2 - 2ab \cos C + b^2$



Some Useful Math (3/4)

Vector relations

Consider a set of mutually perpendicular unit vectors $(\mathbf{i}, \mathbf{j}, \mathbf{k})$ pointing along the three mutually perpendicular axes (X, Y, Z) .

Consider vector $\mathbf{V} = a\mathbf{i} + b\mathbf{j} + c\mathbf{k}$. Its magnitude is $|\mathbf{V}| = V = \sqrt{a^2 + b^2 + c^2}$.

Consider vectors $\mathbf{V}_1 = a_1\mathbf{i} + b_1\mathbf{j} + c_1\mathbf{k}$ and $\mathbf{V}_2 = a_2\mathbf{i} + b_2\mathbf{j} + c_2\mathbf{k}$.

Scalar (dot) product. The scalar (or dot) product of these two vectors is

$$\mathbf{V}_1 \cdot \mathbf{V}_2 = \mathbf{V}_2 \cdot \mathbf{V}_1 = |\mathbf{V}_1| |\mathbf{V}_2| \cos \varphi = V_1 V_2 \cos \varphi$$

where φ is the angle between vectors \mathbf{V}_1 and \mathbf{V}_2 . Expressed through vector components, the scalar product is

$$\mathbf{V}_1 \cdot \mathbf{V}_2 = \mathbf{V}_2 \cdot \mathbf{V}_1 = a_1 a_2 + b_1 b_2 + c_1 c_2.$$

Vector (cross) product. The vector (or cross) product of two vectors \mathbf{V}_1 and \mathbf{V}_2 is

$$\mathbf{V}_1 \times \mathbf{V}_2 = -\mathbf{V}_2 \times \mathbf{V}_1 = |\mathbf{V}_1| |\mathbf{V}_2| \sin \theta \mathbf{u}$$

where θ is the angle between vectors \mathbf{V}_1 and \mathbf{V}_2 and the unit vector \mathbf{u} is perpendicular to both \mathbf{V}_1 and \mathbf{V}_2 . Expressed through vector components, the vector product is

$$\mathbf{V}_1 \times \mathbf{V}_2 = -\mathbf{V}_2 \times \mathbf{V}_1 = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \end{vmatrix} = (b_1 c_2 - b_2 c_1) \mathbf{i} + (c_1 a_2 - c_2 a_1) \mathbf{j} + (a_1 b_2 - a_2 b_1) \mathbf{k}$$

Consider now three vectors \mathbf{a} , \mathbf{b} , and \mathbf{c} .

$$\mathbf{a} \cdot (\mathbf{b} \times \mathbf{c}) = \mathbf{b} \cdot (\mathbf{c} \times \mathbf{a}) = \mathbf{c} \cdot (\mathbf{a} \times \mathbf{b})$$

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = \mathbf{b} (\mathbf{a} \cdot \mathbf{c}) - \mathbf{c} (\mathbf{a} \cdot \mathbf{b})$$

Some Useful Math (4/4)

Vector relations

Differential operator ∇ (del) $\nabla = \frac{\partial}{\partial x} \mathbf{i} + \frac{\partial}{\partial y} \mathbf{j} + \frac{\partial}{\partial z} \mathbf{k}$

Gradient. The gradient of a scalar function $\varphi(x, y, z)$

$$\text{grad } \varphi = \nabla \varphi = \frac{\partial \varphi}{\partial x} \mathbf{i} + \frac{\partial \varphi}{\partial y} \mathbf{j} + \frac{\partial \varphi}{\partial z} \mathbf{k}$$

Divergence. The divergence of the vector function \mathbf{A} ,

$$\mathbf{A} = \mathbf{A}(x, y, z) = A_x(x, y, z) \mathbf{i} + A_y(x, y, z) \mathbf{j} + A_z(x, y, z) \mathbf{k}$$

$$\text{div } \mathbf{A} = \nabla \cdot \mathbf{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

Curl. The curl, or rotation, of the vector function \mathbf{A}

$$\text{curl } \mathbf{A} = \text{rot } \mathbf{A} = \nabla \times \mathbf{A} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z} \right) \mathbf{i} + \left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x} \right) \mathbf{j} + \left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y} \right) \mathbf{k}$$

Laplacian

$$\Delta \varphi = \nabla^2 \varphi = \nabla \cdot \nabla \varphi = \text{div grad } \varphi = \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2}$$

Gauss's theorem (divergence theorem)

$$\int_V \text{div } \mathbf{A} \, dV = \int_S \mathbf{A} \cdot \mathbf{n} \, da$$

Stoke's theorem

$$\oint_C \mathbf{A} \cdot d\mathbf{l} = \int_S \text{curl } \mathbf{A} \cdot \mathbf{n} \, da$$

ASTE 520 Spacecraft Design



Fall 2023

Mike Gruntman

Department of Astronautical Engineering
Viterbi School of Engineering
University of Southern California
Los Angeles

Section 00, Part 2

Organization of the Class

Spacecraft Design

- Organization of the class
- Content
- Schedule
- Astronautics Program
- Course notes
- Other supporting material
- Homework
- Exams
- Distance Education Network DEN

Organization of the Class – First Lecture

- Class Notes are essential and mandatory for ASTE 520
- On-campus and remote students: download Class Notes from the class web site at DEN (<http://courses.uscdcn.net>)
password required (see slides 28-29)
- Teaching will be done directly from the notes – bring the required materials to the class
- Files for the first class meeting on **August 24, 2023**:
[2023-Fall_ASTE-520_Sec_00_part-1_no_pswd.pdf](#)
[2023-Fall_ASTE-520_Sec-00_part-2_no_pswd.pdf](#) (this file)
[2023-Fall_MG_SCD_01.pdf](#) (self study for homework)
[2023-Fall_MG_SCD_02.pdf](#)

Attention: read this section of Class Notes for rules

Contents – ASTE 520

- **Section 00**
Part 1 and Part 2
Organization of the Class
- **Section HW**
Homework Problems
- **Section 01**
Brief History
- **Section 02**
Universe, Galaxy, Solar System
- **Section 03**
Space Environment

- **Section 04**
Orbital Mechanics
- **Section 05**
Mission Geometry
- **Section 06** (self study)
Spacecraft and Mission Design Overview. Operations. Reliability
- **Section 07**
Spacecraft Attitude Determination and Control

- **Section 08**
Spacecraft Propulsion
- **Section 09**
Launch Systems
- **Section 10**
Communications
- **Section 11**
Electric Power Systems
- **Section 12**
Thermal Control
- **Section 13**
Structures and Mechanisms

Objectives of the Course

- This course is of a survey nature, meant to acquaint the student with key aspects of spacecraft system design.
- The class notes and textbook provide most of the details, and the homework is designed to provide a first-level understanding.
- We will learn the basic nomenclature and vocabulary, so that you can converse with understanding with subsystem specialists.
- No pundit will ever “snow” you.

Spacecraft design is essentially an interdisciplinary sport that combines science, engineering, and external phenomena. The course provides basics of systems engineering of space systems.

Objectives of the Course

- Whenever possible, you will learn the design considerations which come into play in laying out a mission and a preliminary design.
- You will learn some basics. It is assumed, however, that everyone has taken undergraduate physics, mathematics, and some engineering classes.
- You are expected to **remember some *Physics and Mathematics***
- Satellite system design is an essentially interdisciplinary sport that combines engineering, science, and external phenomena.

Instructor

- detailed biographical sketch in *Section 00, Part 1*
- communications on the first-name basis most welcome
- E-mail mikeg@usc.edu
- URL <http://astronauticsnow.com>

Mike Gruntman

Professor of Astronautics,
Chairman 2004-2007 (founding chairman), 2016-2019

Department of Astronautical Engineering

Tel. 213-740-5536
Office: OHE-530G
mikeg@usc.edu



Specialist in astronautics, space physics, space sensors and instrumentation, space missions, rocketry, spacecraft technologies, space education, and space and rocket history; Co-Investigator (Co-I) and participant in several NASA missions

300+ scholarly publications,
incl. 6 books (incl. IAA award)

ASTE-520 – Is This Course for You?

- **If you are** a student, engineer, or scientist in astronomy, physics, chemistry, mathematics, Astronautical Engineering (E), Aerospace E, Aeronautical E, Civil E, Electrical E, Mechanical E, Industrial E, Systems E, Nuclear E, Chemical E, Computer E,
- **If you work or plan (want) to work** in the space or defense industry or in government space research and development centers (NASA, Space Force, Air Force, Navy, Army, IC, DOE, NOAA, ...) or space mission operations and control centers

and/or

This course – ASTE-520 – IS FOR YOU

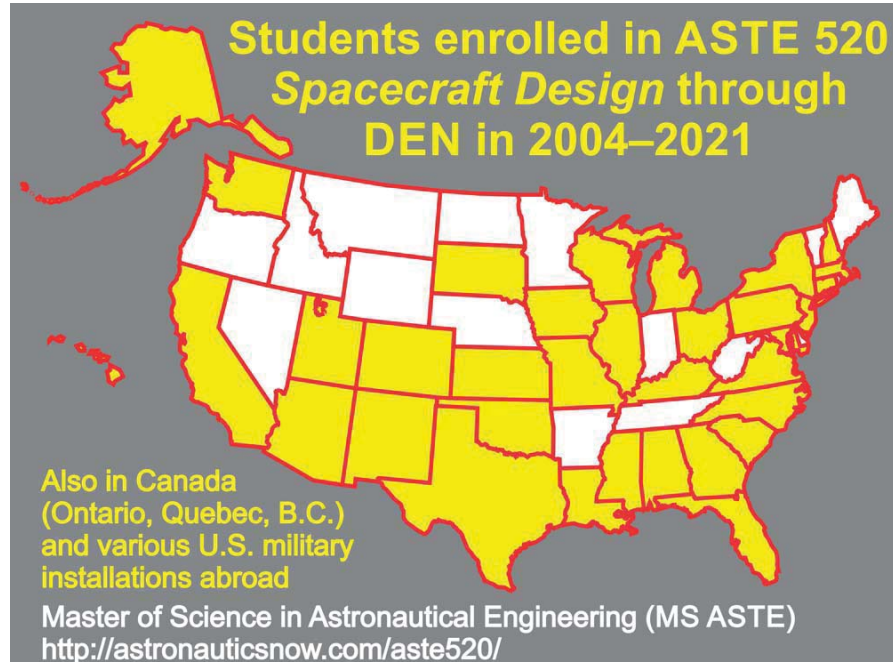
In addition to classroom, ASTE-520 *Spacecraft Design* is simultaneously offered through the USC Viterbi's *Distance Education Network* (DEN) and can be taken by students anywhere in the United States (and the world).

ASTE 520 Spacecraft Design

ASTE-520

Spacecraft Design reaches students anywhere in the United States and abroad through the Distance Education Network (DEN)

More than **2300** students since 1994



Astronautics at USC

- USC established the *Astronautics and Space Technology Division (ASTD)*, operating as an independent academic department, in August 2004
- renamed (July 1, 2010) *Department of Astronautical Engineering (ASTE)* a unique pure-space-engineering Department in the United States
- offers BS, BS Minor, MS, Engineer, and PhD degrees and Graduate Certificate in *astronautical engineering* (postcode *ASTE*)
- Combines science and engineering fundamentals with highly specialized classes taught by adjunct faculty and part-time lecturers (top specialists in the trenches)
- ASTE is responsible for programs in astronautics and space technology at USC, concentrating on meeting the educational and research needs of the space and defense industries, government R&D centers, and academia

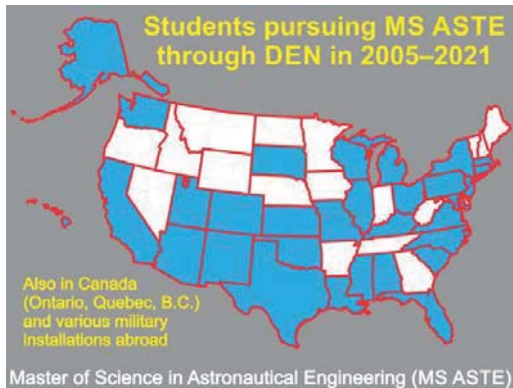
USC Astronautics program history, focus, rationale, and organization



Acta Astronautica, v. 103, 92-105, 2014
 also IAC and AIAA papers – download
<http://astronauticsnow.com/aste.pdf>

National statistics (American Society of Engineering Education – ASEE) combines students in **astronautical, aeronautical, and aerospace** engineering in one broad group (>65 departments in the United States and >55 Master's programs)

>3% nationally awarded Master's degrees in astronautical/aeronautical/aerospace engineering



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2023_MG_SCD_00

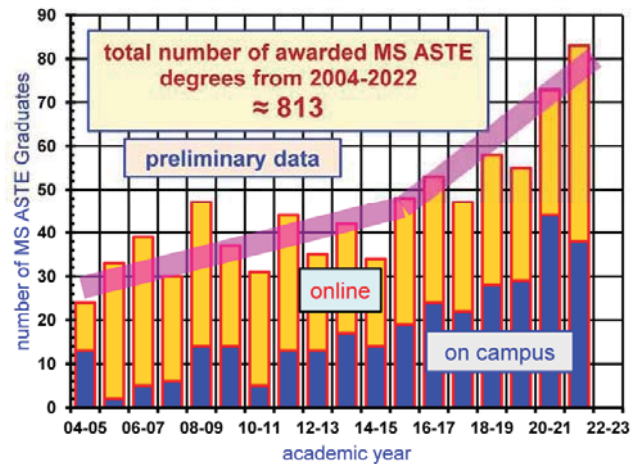
Fall 2023

11/34

Some statistics

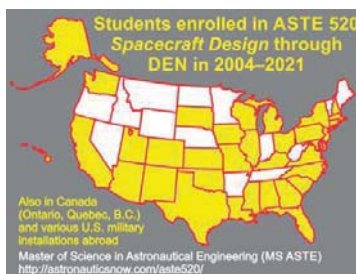
800+ MS ASTE degrees awarded from 2004–2022

USC/VSOE degrees awarded:
Master of Science in Astronautical Engineering

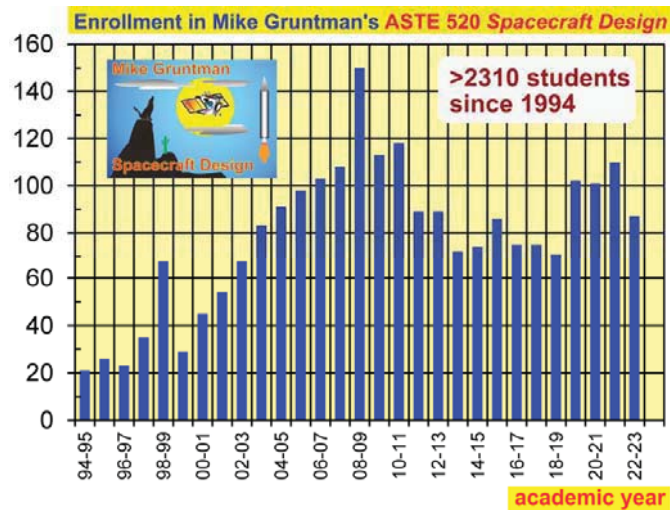


ASTE 520 Spacecraft Design

Each year, students hail from 10–14 States of the Union



Popular Course – Enrollment Dynamics



Enrollment depends on offering frequency and restrictions by other departments

About three quarters of enrolled students pursue degrees in *Astronautical Engineering*. Other students pursue other engineering degrees (electrical, mechanical, system, aerospace, civil, computer, etc.). Most students pursue MS; 5–10% pursue PhD.

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2023_MG_SCD_00

Fall 2023

12/34

ASTE 520 – Spacecraft Design

- **Prerequisite**

Graduate standing in engineering or science

- **Class Notes**

Class Notes are essential and mandatory for the course. Download the Notes (>800 p) from the class web site at DEN (<http://courses.uscden.net>).

- **Class Procedure**

Teaching will be done directly from the notes. It is advisable to bring appropriate materials to class.

- First HW assignments (1,2) due on **August 31, 2023**.
- There are **30** homework assignments. Submission schedule is in Section 00, Part 1.
- **Late homework** may be submitted **within two weeks** after the due date but not later (\equiv must be received by TAs) than **November 16, 2023** (inclusive).
Late homework will be graded; the grade will be reduced by **50%**.
No late homework submissions after November 16, 2023. (“No” means “No.”)
- No “make up” (home)work (extra work) is possible. No special “deals” on homework submission, regardless of the cause, are possible.
“No” means “No.” “Regardless” means “Regardless.”
- Homework assignments and solutions are posted at the class web site at DEN (<http://courses.uscden.net>); solutions usually posted one week after the due date.
- On-campus students submit homework in class. Online DEN students submit homework through <http://courses.uscden.net>.

Homework

Students must keep records of their HW assignment scores and check with TAs 2-3 times during the semester the accuracy of the scores in our records. Simply email TAs the scores and they will check the accuracy.

Exams and Grading

Unless advised otherwise, the Midterm and Final exams will be conducted for all students (on-campus and online DEN) fully online.

Time given for Pacific Time Zone

Grading ASTE-520

Homework 20%

Midterm Exam 40%

Final Exam 40%

- Midterm Exam
19 October (Thursday), 2023
7:00 – 9:00 p.m. (120 min)
- Final Exam (cumulative; entire semester content; focused on 2nd part)
7 December (Thursday), 2023
7:00 – 8:30 p.m. (90 min)

- If the exams are fully online and electronic, then there will be no restrictions on the use of laptops, software, etc.
- If the exams are in a different format, we will announce the arrangements in advance.

The time of the exams will be adjusted for students in different time zones.

Exams are open-book, -notes, -etc

Typical Grade Distribution

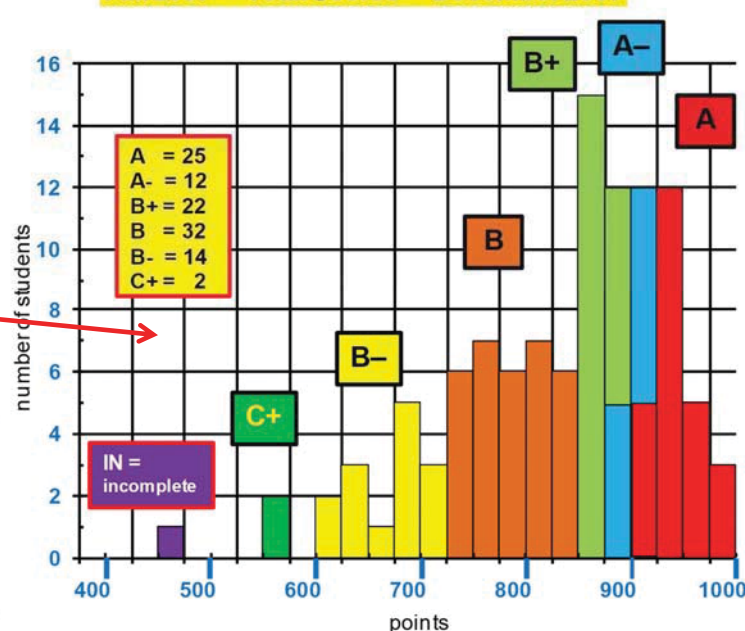
Important question by enrolled students:

What is a typical grade distribution in the class?

Example

ASTE 520
Spacecraft Design
Fall 2007
Grade Distribution
(108 students)

ASTE 520 Spacecraft Design
Fall 2007 - Total Scores - December 2007



Organization of the Class

- **Class Attendance:** Free walk in / walk out
 - If sleep, do not snore (on-campus rule only)
 - No food (on campus – DEN's rule)
 - Cell phones and pagers off (be nice)
- **Questions**
 - Any aspect of astronautics and rocketry can be discussed
 - Fear not! Questions are welcome.

- **Academic Integrity**

See Notes ([Section 00, Part 1](#)) and familiarize yourself with the Academic Integrity guidelines in the USC student handbook.

 - **Bottom line**

Homework, exams, etc. are **individual effort**

- Class notes are **mandatory and essential** for the class – bring the required sections to the class
- Download class notes from the class D2L web site at DEN (<http://courses.uscden.net>).
password required (slides 28–29)
many students print two slides/pages per sheet of paper

Lecture webcasts

All lectures are available through Distance Education Network (DEN) to **all students**, on-campus and online/distance, enrolled in the class during the entire semester
a few-hour delay for on-campus students

Office Hours – ASTE-520

- **Teaching Assistant's office hours**
to be announced (TBA)

Pacific Time

- **Instructor's office hours**

Tuesday (WebEx) 3:00 p.m. – 4:00 p.m.

Thursday (in person) 3:00 p.m. – 4:00 p.m.

Class Notes and Textbook

Required -- Course Notes (>800 pages)

Mike Gruntman, *Spacecraft Design, ASTE-520 Notes, Fall 2023*

For your personal use only. Copyright protected.

Recommended books

J. R. Wertz, D.F. Everett, and J.J. Puschell (eds.), *Space Mission Engineering: The New SMAD*, Microcosm, 2011



W. J. Larson and J. R. Wertz (eds), *Space Mission Analysis and Design*, Kluwer Academic Publ. and Microcosm, 1999; other editions

P. Fortescue, G. Swinerd, J. Stark, *Spacecraft Systems Engineering*, Wiley, 2011, other editions

V. L. Pisacane, *Fundamentals of Space Systems*, Oxford Univ. Press, 2005; other editions

M. Gruntman, *Fundamentals of Space Missions: Problems with Solutions*, Interstellar Trail Press, 2022 (paperback and Kindle) <http://astronauticsnow.com/fsm2022/>

Insist your institutional and local libraries get these books for you to use.

Selected/Recommended Books

- AIAA *Aerospace Design Engineers Guide*, AIAA, 1993.
- B. N. Agrawal, *Design of Geosynchronous Spacecraft*, Prentice Hall, 1986.
- R. R. Bate, D. D. Mueller, and J. E. White, *Fundamentals of Astrodynamics*, Dover, 1971.
- C. D. Brown, *Spacecraft Mission Design*, AIAA, 1992.
- C.D. Brown, *Spacecraft Propulsion*, AIAA, 1996.
- V. A. Chobotov, *Orbital Mechanics*, AIAA, 1991.
- P. Fortesque, G. Swinerd, and J. Stark, *Spacecraft Systems Engineering*, John Wiley and Sons, 2011 (4th edition).
- M. D. Griffin and J. R. French, *Space Vehicle Design*, AIAA, 2004 (and other editions).
- M. Gruntman, *Blazing the Trail: The Early History of Spacecraft and Rocketry*, AIAA, 2004.
- M. Gruntman, *Fundamentals of Space Missions: Problems with Solutions*, Int. Tr. Press, 2022
- R.W. Humble, G.N. Henry, and W.L. Larson, eds., *Space Propulsion Analysis and Design*, McGraw-Hill, 1995 (and later editions).
- S. J. Isakowitz, J. Hopkins, J.P. Hopkins Jr., *International Reference Guide to Space Launch Systems*, AIAA, 2004 (4th edition).
- A. S. Jursa, ed., *Handbook of Geophysics and the Space Environment*, Air Force Geophysics Laboratory, Hanscom AFB, 1985.
- M. H. Kaplan, *Modern Spacecraft Dynamics and Control*, John Wiley, 1976.

Selected/Recommended Books (cont.)

- V. L. Pisacane and R. C. Moore, *Fundamentals of Space Systems*, Oxford Univ. Press, 1994
- V.L. Pisacane, *The Space Environment and its Effects on Space Systems*, AIAA, 2008.
- D. Roddy, *Satellite Communications*, McGraw-Hill, 1996.
- C.T. Russel, J.G. Luhmann, and R.J. Strangeway, *Space Physics. An Introduction*, Cambridge Univ. Press, 2016.
- G. P. Sutton and O. Biblarz, *Rocket Propulsion Elements*, John Wiley and Sons, 2020 (and earlier editions).
- G.P. Sutton, *History of Liquid Propellant Rocket Engines*, AIAA, 2005.
- T. Tascione, *Introduction to the Space Environment*, Orbit Book Co., 1988.
- A. Tribble, *The Space Environment*, Princeton University Press, 1995.
- *TRW Space Data*, TRW Space and Technology Group, 1992.
- D.A. Vallado, *Fundamental of Astrodynamics and Applications*, Microcosm Press and Kluwer academic Publishers, 2001 (and later editions).
- J. R. Wertz, ed., *Spacecraft Attitude and Determination Control*, Kluwer, 1978.
- W.E. Wiesel, *Spaceflight Dynamics*, McGraw-Hill, 1997 (and other editions).

Many, many, many other books – see instructor's web site
<http://astronauticsnow.com/AstroBooks/>

Other Sources of Information

- Several (course-related) video clips – links (YouTube) at <http://astronauticsnow.com/vp/>
- A large number of books can be recommended for this class – check the list of recommended books at <http://astronauticsnow.com/AstroBooks/>
- Publications of professional societies (journals, conference proceedings, etc)
- Trade pubs – usually good; mainstream media – often embarrassing
- World Wide Web (WWW)
 - caution – a lot of unprofessional and inaccurate information (including pure, unmitigated garbage) out there



Class websites

Class web site at DEN: <http://courses.uscdcn.net>

Public (permanent) class web site: <http://astronauticsnow.com/aste520/>

Program frequently asked questions: <http://astronauticsnow.com/msaste/faq.html>

Professional Societies and Groups

- It is highly advisable to become a member of professional societies and groups
- Membership helps professional growth, networking, etc.
- *Primary society* for space engineers is
American Institute of Aeronautics and Astronautics (AIAA)
<http://www.aiaa.org>



- Many other professional societies for scientists and engineers working in various fields related to space exploration and space technology
AAS, AGU, APS, IEEE, OSA, SPIE, ,

Professional networking group on LinkedIn

http://astronauticsnow.com/astrousc_linkedin/

USC Astronautics Alumni, Students, Faculty, and Friends

**USC
Astronautics**

USC Astronautics Alumni, Students, Faculty, and Friends

Connect with your fellow Astro-Trojans. Ad Astral

In order to get the T-shirt, and follow the poster...

NASA Administrator Charles Bolden (left) at the 49th AIAA Aerospace Meeting in Orlando, Fla., with the USC-Astronautics rocket-scientist Mike Gruntman on the right. VSOE MAPP's Billy Schwerin is behind the center. January 5, 2011.

Apollo astronaut Buzz Aldrin (center) and the instructor of ASTE's Space Studio Madhu Thangavelu (right) with the USC-Astronautics rocket at the ASTE graduate student Sam Barbour is next to Aldrin and Mike the left. December 13, 2012.

This USC Astronautics LinkedIn networking group launched on 11 April 2009. More than 300 members as of January 2012.

http://astronauticsnow.com/astrousc_linkedin/

USC Astronautics Alumni, Students, Faculty, and Friends

USC Astronautics Alumni, Students, Faculty, and Friends

USC Master of Science in Astronautical Engineering: Overview (video; 53 min)

USC program Master of Science in Astronautical Engineering: update - April 21, 2011 (pdf)

LinkedIn Group

USC Astronautics Alumni, Students, Faculty, and Friends

The network of the alumni, students, faculty, and friends of the **USC Astronautics**, a rapidly growing program offering degrees in astronautical engineering. Hundreds of our alumni work in the leading American space companies and government research and development centers.

The true story ... Now it can be told

We welcome not only our **current and former students** with the degrees in **Astronautical Engineering** (or the old degree **Aerospace Engineering, Astronautics**), but also **all current and former USC students** who took our space classes and are part of the great space enterprise. **USC Astronautics** began as a space engineering specialization in the Viterbi School of Engineering of the University of Southern California. Today, it is an independent space-focused Department of Astronautical Engineering in the Viterbi School. (**Astronautics program history, focus, dynamics.**) Please check the **statistics** on the number of awarded degrees (about 40 MS degrees annually during the last four academic year) and program reach.

In addition, we welcome to USC-Astronautics LinkedIn group the **program friends**, all those space professionals (space/defense industry, national labs and FFRDCs, government, academia, space advocates) who are interested in and support our program.

Periodically, our group members post job offerings -- many will certainly find them useful.

http://astronauticsnow.com/astrousc_linkedin/

USC Astronautics

USC Astronautics networking group launched in 2009

>650 members

http://astronauticsnow.com/astrousc_linkedin/

On-Campus and DEN Instructions

Homework must be submitted by 6:00 p.m. (Pacific) on Thursday

- On all homework pages, put your name (no ID) and course number ASTE-520
- All students (on campus and online DEN) submit homework (and receive graded homework) electronically
- On-campus students must set up access to DEN webcasts. If you are going to be absent from a USC class, you can watch the lecture at a convenient time through webcast.

Exams

- Final and Midterm will likely be fully online (electronic) for all students.
- In the past (before the pandemic), the exams were held on campus for students in the Los Angeles area. Outside this area, the exams were arranged and proctored at remote sites by DEN.
- If you absolutely have to be on a business trip during the exam – contact the instructor in advance.

Exams

- If special arrangements (e.g., DSP) for exams are required, please contact the instructor 2-3 weeks before the exam.

All Students – Homework

- No homework can be submitted to the instructor's e-mail address (unless specifically directed by the instructor).
- Do not copy to the instructor your submissions to DEN.

Contact TA first if homework/exam scores require adjustment. If no agreement is reached, then contact the instructor.

GAPP/DEN and MS ASTE – Students Resources

- VSoE Current Graduate Students – <https://viterbigrad.usc.edu/>
- VSoE Distance Education Network (DEN) – DEN Student Support
<https://viterbigradadmission.usc.edu/denviterbi/experience/>
- Login to the class web site at DEN, homework submissions, etc. at
<http://courses.uscdcn.net>
- GAPP/DEN student resources –
<https://viterbigrad.usc.edu/academic-services/academic-advisement/>
 - Print names and telephone numbers of GAPP/DEN contact persons
 - Use it! Do not be shy! **Call them!** **E-mail them!** **They are here to help!**



MS ASTE *Frequently Asked Questions FAQ*

<http://astronauticsnow.com/msaste/faq.html>

long-term class schedule —

http://astronauticsnow.com/msaste/astd_ms_class_schedule.pdf

Survey and Password

- E-mail the survey (next slide) to the instructor (mikeg@usc.edu) on or after **August 13, 2023** as a **plain text in your message** (do not attach as an MS Word or PDF file) with the **subject line ASTE-520 Survey**. (Note that your instructor has usually a heavy work schedule in August – expect possible delays – with his response.)
 - Survey is important for communications with students
 - In response to your survey, the instructor will e-mail you the password to the class notes and homework solutions (posted on the class web site at DEN)
 - Do not email the survey earlier than instructed above. If emailed earlier, it will be deleted and disregarded.

Survey – e-mail to Instructor

(as plain text in your e-mail message)

1. Name (**no SSN or student ID, please!!!**)

2. Degree(s) attained: university and field (e.g., AstronauticalE, MechanicalE, ElectricalE, AerospaceE, SystemE, Physics, Astronomy, ...)

3. Degree sought (MS, PhD, Certificate, BS, Progressive 4+1, PDP, ...) and field/major (AstroE, EE, ME, CompE, AE, CivilE, ChE, Phys, Chem, Math, ...)

4. Are you a full-time student? Or, do you work full time and study part time?
If you work – tell me where (e.g., NASA–JPL, Aerospace Corp, NASA–JSC, SMC, LAAFB, Boeing El Segundo, Orbital, Northrop-Grumman, VeryCoolRockets Inc., etc., ...)

5. Location of your place of residence/work: city, state

6. E-mail

Note that USC, VSOE, and departments email you only to your @usc.edu email addresses

7. Student status (regular admitted, limited status, ..., undergrad)

The information in this survey is for your instructor only. It is in your interest to provide me with the ways to reach you if and when needed. I will also compile class statistics. You will thus know who (statistically) your peers are.

Units and Constants

1 inch	=	2.540 cm	
1 mil	=	10^{-3} inch	= 25.4 μ m
1 foot	=	30.48 cm	
1 statute mile	=	1609 m	= 1.609 km
1 nautical mile	=	1852 m	= 1.852 km
1 ounce	=	28.35 g	
1 lb (pound)	=	0.4536 kg	
1 lbf	=	4.448 N	
1 slug	=	1.459×10^4 g	= 14.59 kg
1 atm	=	1.013×10^5 N/m ²	= 1.013 25 bar
1 psi	=	6.894×10^3 N/m ²	= 6.805×10^{-2} atm

Units and Constants

Electron charge (e)	=	$1.6022 \times 10^{-19} \text{ C}$
Electron-volt (eV)	=	$1.6022 \times 10^{-19} \text{ J}$
Atomic mass unit (amu)	=	$1.6605 \times 10^{-27} \text{ kg}$
Boltzmann constant (k_B)	=	$1.38065 \times 10^{-23} \text{ J K}^{-1}$
Stefan-Boltzmann constant (σ_{SB})	=	$5.6704 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Astronomical Unit (AU)	=	$1.496 \times 10^{11} \text{ m}$
Earth equatorial radius (R_e)	=	6 378.14 km
Gravitational constant (G)	=	$6.6726 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$
Free fall acceleration (g)	=	9.80665 m/sec ²
μ_{EARTH}	=	$3.9860 \times 10^{14} \text{ m}^3/\text{sec}^2$
μ_{SUN}	=	$1.3271 \times 10^{20} \text{ m}^3/\text{sec}^2$

Units and Constants: References

- You must be confident in juggling units: *meter, mile, nautical mile, astronomical unit, pound, foot, tor, Newton, radian, ...* and prefixes kilo, nano, deka, femto, ...
- Conversion coefficients and physical constants (G, c, h, k, \dots) can be found in many reference publications (e.g., *AIAA Aerospace Design Engineers Guidebook, Handbook of Chemistry and Physics, etc*).
- Important reference documents on the web site of the **National Institute of Standards and Technology (NIST)**
 A guide to the use of the [metric] International System of Units (SI)
<http://physics.nist.gov/Pubs/SP811/sp811.html>
 Physical constants – <http://physics.nist.gov/cuu/Constants/index.html>
- Compile lists (or make a copy of the pages) with the conversion coefficients and physical constants as the class progresses and attach them to your notes. The lists will be exceptionally useful (and time-saving) for working on the homework assignments and exams.

Greek alphabet

α	A	alpha	ι	I	iota	ρ	P	rho
β	B	beta	κ	K	kappa	σ	Σ	sigma
γ	Γ	gamma	λ	Λ	lambda	τ	T	tau
δ	Δ	delta	μ	M	mu	υ	Υ	upsilon
ϵ	E	epsilon	ν	N	nu	ϕ	Φ	phi
ζ	Z	zeta	ξ	Ξ	xi	χ	χ	chi
η	H	eta	\omicron	O	omicron	ψ	Ψ	psi
θ	Θ	theta	π	Π	pi	ω	Ω	omega
			ϖ	—	“curly pi,” an alternative form of π			
			ς	—	an alternative form of σ			

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