ASTE 520

Spacecraft Design

Fall 2017

Mike Gruntman

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

Spacecraft Design, Fall 2017
(set of notes on spacecraft design)
Mike Gruntman, 2017

ASTE 520 *Spacecraft Systems 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 in government space R&D centers or in space operations, then ...**

This is a course (on space systems) that you must take.

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

The course is popular at USC. It is among largest graduate space systems and space technology courses in the United States, with **more than 1260 students during the last 12 years** alone.

Academic year 2017–2018

ASTE520 *Spacecraft Systems Design* is offered **only in the fall (2017)** semester.

Fall 2017 Class enrollment is unlimited.

For students enrolled in the class:

Course materials for *ASTE-520 Spacecraft Systems Design* will be posted on the class web site at DEN around August 14, 2017.

Spring 2018 Course not offered

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-136 Fall 2017

Class	Date	Subject	NS	W&E&P New SMAD (L&W SMAD) Chapters	HW Due
1	Aug 24	Organization of the class. History of rocketry and space (self study). Universe, galaxy, solar system.	0 1 2	1	
2	Aug 31	Space environment.	3	7 (8)	1,2
3	Sep 07	Orbital mechanics.	4	9 (5,6,7)	3,4,5
4	Sep 14	Orbital mechanics. Space mission geometry.	4 5	8,9 (5,6,7) 8,9 (5,6,7)	6, 7, 8
5	Sep 21	Space mission geometry. Spacecraft and mission design overview. Facilities. Operations. Reliability.	5 6	8 (5) 1,3,4,6,14,24,28,29 (1,3,4,10,14,15,19)	9,10,11
6	Sep 28	Attitude determination and control (ADC).	7	19 (10,11)	12,13,14
7	Oct 05	Attitude determination and control (ADC). Spacecraft propulsion.	7 8	19 (10,11) 18 (17,18)	15,16,17
8	**Oct 12**	**MID-TERM**	**7:00–9:00 p.m., on campus, room TBD**		
9	Oct 19	Spacecraft Propulsion.	8	18 (17,18)	18,19,20
10	Oct 26	Launch systems. Communications	9 10	26,27 (17,18) 16,21 (10,11,13)	21,22
11	Nov 02	Communications	10	16,21 (10,11,13,16)	23,24
12	Nov 09	Electric Power systems.	11	21 (10,11)	25,26,27
13	Nov 16	Thermal control.	12	22 (10,11)	28,29
14	Nov 30	Structures and mechanisms	13	22 (10,11)	30,31,32
15	**Dec 07**	**FINAL EXAM**	**7:00–8:30 p.m., on campus, room TBD**		

W&E&P New SMAD = Wertz, Everett, Puschell, The New SMAD **L&W SMAD = Larson and Wertz, SMAD**

ASTE 520 Spacecraft Design Notes

Contents

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
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- ⇒ reaction/momentum wheel
- ⇒ example of problems (reaction/momentum wheels)
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Section 08
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- ⇒ 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
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- ⇒ propellant tanks
- ⇒ propellant expulsion
- ⇒ liquid propellants
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- ⇒ gelled propellants
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- ⇒ grains
- ⇒ thrust vector control
- ⇒ electric propulsion
- ⇒ electrostatic thrusters
- ⇒ field emission electric propulsion (FEEP) and colloid thrusters
- ⇒ resistojet
- ⇒ arcjet
- ⇒ magnetoplasmadynamic thrusters (MPD)

Section 09
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- ⇒ 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
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- ⇒ Shannon's Law
- ⇒ origins of noise
- ⇒ noise figure
- ⇒ link design
- ⇒ effect of atmosphere, rain, snow
- ⇒ modulation
- ⇒ encoding
- ⇒ BER
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- ⇒ multiple access techniques
- ⇒ data compression
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- ⇒ transponder
- ⇒ telemetry data formats
- ⇒ data handling
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Section 11
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- ⇒ subsystem elements
- ⇒ design drivers
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- ⇒ Planck and Stefan-Boltzmann Laws
- ⇒ thermal control components
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- ⇒ heaters
- ⇒ louvers
- ⇒ heat pipes
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- ⇒ thermal testing

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- ⇒ sources of structural loads
- ⇒ launch
- ⇒ acoustic environment
- ⇒ basics of mechanics of materials
- ⇒ flexible-body dynamics
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- ⇒ materials
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- ⇒ examples
- ⇒ spacecraft weight estimate
- ⇒ tests and simulations

ASTE 520 Spacecraft Design Fall 2017

Home Work Schedule

Problem	due date
1	08/31/2017
2	08/31/2017
3	09/07/2017
4	09/07/2017
5	09/07/2017
6	09/14/2017
7	09/14/2017
8	09/14/2017
9	09/21/2017
10	09/21/2017
11	09/21/2017
12	09/28/2017
13	09/28/2017
14	09/28/2017
15	10/05/2017
16	10/05/2017
17	10/05/2017
	10/12/2017
18	10/19/2017
19	10/19/2017
20	10/19/2017
21	10/26/2017
22	10/26/2017
23	11/02/2017
24	11/02/2017
25	11/09/2017
26	11/09/2017
27	11/09/2017
28	11/16/2017
29	11/16/2017
30	11/30/2017
31	11/30/2017
32	11/30/2017

Mike Gruntman, *Professor of Astronautics* tel. 213–740–5536
Department of Astronautical Engineering, MC–1192 mikeg@usc.edu
University of Southern California http://astronauticsnow.com
Los Angeles, California 90089–1192

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 experimental 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 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 nearly 300 scholarly publications, including four 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 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, known today as the Department of Astronautical Engineering (ASTE). He again serves as the ASTE 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 a member of the American Physical Society (APS) and American Geophysical Union (AGU). Dr. Gruntman is Member (Academician) of the International Academy of Astronautics (IAA).

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. In 2006, his AIAA-published book on history of rocketry and spacecraft received an award from the International Academy of Astronautics.

Gruntman 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, for book publishers, and for 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 in other government agencies.

Department of Astronautical Engineering (ASTE)

In August 2004, Dean of Engineering (now USC President) Prof. Max Nikias established a new independent academic unit to take the full advantage of rapidly growing opportunities in space exploration and technology. This *Department of Astronautical Engineering* (ASTE) offers the full set of degrees (BS, BS Minor, MS, Engineer, PhD, and Graduate Certificate) in ***Astronautical Engineering***. USC's Master's program in Astronautical Engineering (MS ASTE) is highly visible nationally and internationally and among largest in the United States.

More information on history of Astronautical Engineering at USC – see next page.

ASTE is responsible for VSoE programs in astronautics and space technology, concentrating on meeting the educational and research needs of interest to the space and defense industries, government research and development centers, and academia.

Please contact Astronautics faculty and ASTE Senior Administrator Ms. Dell Cuason (RRB–228; tel. 213–821–5817; cuason@usc.edu) and Student Adviser Ms. Hayley Peltz (RRB–223; tel. 213–821–4234; hpeltz@usc.edu) should you have any questions. Dell and Hayley are your contact persons for all questions regarding class registration and admission or transfer to the program in astronautical engineering.

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 Adviser Ms. Hayley Peltz (RRB–223; tel. 213–821–4234; hpeltz@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 Adviser Ms. Hayley Peltz (RRB–223; tel. 213–821–4234; hpeltz@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

USC Astronautics program history, focus, rationale, and organization

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Advanced degrees in astronautical engineering for the space industry

Mike Gruntman*

Department of Astronautical Engineering, University of Southern California, Los Angeles, CA 90089-1192, USA

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ABSTRACT

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 mid-1990s and expanded into a large nationally-visible program. In addition to on-campus full-time students, it reaches many working students on-line 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:// http://astronauticsnow.com/2014aste.pdf

or from http://astronauticsnow.com/SpaceEducation/

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 applicant's record which includes GPA, GRE, and two letters of recommendation.

Required items:	**Send To**
Application	Office of Grad. and Int'l Admission
Official Transcript(s)	Office of Grad. and Int'l Admission
General Record Exam	Office of Grad. and Int'l Admission
TOEFL (international students only)	Office of Grad. and Int'l Admission
Recommendation Letters	Office of Grad. and Int'l Admission

Application

All applications should be submitted on-line 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 on-line 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.

Integrity

Academic integrity of all students participating in this course is of the 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 to the *Department of Public Safety* http://capsnet.usc.edu/department/department-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)

Taylor's theorem

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

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

An alternative form

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

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

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

Examples (elementary functions):

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

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

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

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

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

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

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

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

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

Some Useful Math (2)

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

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

and

$$\iiint F(x,y,x)\,dxdydz = \iiint G(u,v,w)\,\frac{\partial(x,y,x)}{\partial(u,v,w)}\,dudvdw$$

where the Jacobian determinant is

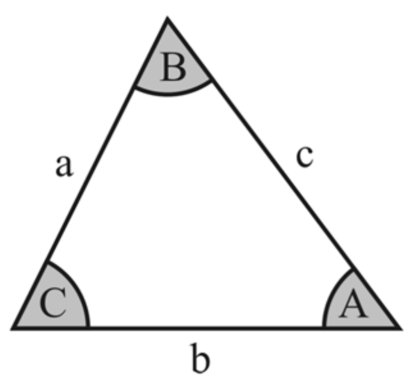
$$\frac{\partial(x,y,x)}{\partial(u,v,w)} = \begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial y}{\partial u} & \frac{\partial z}{\partial u} \\ \frac{\partial x}{\partial v} & \frac{\partial y}{\partial v} & \frac{\partial z}{\partial v} \\ \frac{\partial x}{\partial w} & \frac{\partial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

Plane oblique triangle

$A + B + C = \pi = 180°$

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

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



Some Useful Math (3)

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 $|\mathbf{V}|=\mathrm{V}=\sqrt{a^2+b^2+c^2}$.

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

$$\mathbf{V}_1\cdot\mathbf{V}_2=\mathbf{V}_2\cdot\mathbf{V}_1=|\mathbf{V}_1|\,|\mathbf{V}_2|\cos\varphi=\mathrm{V}_1\ \mathrm{V}_2\ \cos\varphi$$

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

$$\mathbf{V}_1\cdot\mathbf{V}_2=\mathbf{V}_2\cdot\mathbf{V}_1=a_1a_2+b_1b_2+c_1c_2\ .$$

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

$$\mathbf{V}_1\times\mathbf{V}_2=-\mathbf{V}_2\times\mathbf{V}_1=\begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ a_1 & b_1 & c_1\\ a_2 & b_2 & c_2\end{vmatrix}=(b_1c_2-b_2c_1)\mathbf{i}+(c_1a_2-c_2a_1)\mathbf{j}+(a_1b_2-a_2b_1)\mathbf{k}$$

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)

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 $\varphi(x, y, z)$

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

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

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

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

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

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

Laplacian

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

Gauss's theorem (divergence theorem)

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

Stoke's theorem

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

ASTE 520 Spacecraft Design

Fall 2017

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.uscden.net)

  password required (see Slides 33–34)
- Teaching will be done directly from the notes – bring the required materials to the class
- Files for the first class meeting on **August 24, 2017**:

  2017-Fall_MG_SCD_00_part_1_no_pswd.pdf

  2017-Fall_MG_SCD_00_part_2_no_pswd.pdf (this presentation)

  2017-Fall_MG_SCD_01.pdf (self study for homework)

  2017-Fall_MG_SCD_02.pdf

Attention: read this section of Class Notes for rules

Contents – ASTE 520

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

Mike Gruntman

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

Department of Astronautical Engineering

Tel. 213–740–5536
Office: RRB–224
mikeg@usc.edu

- 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

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 pubs,
incl. 4 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, ………

  and/or

- **If you work or plan (want) to work** in the space or defense industry or in government space research and development centers (NASA, Air Force, Navy, Army, IC, DOE, NOAA, …) or space mission operations and control centers

This course – ASTE 520 – IS FOR YOU

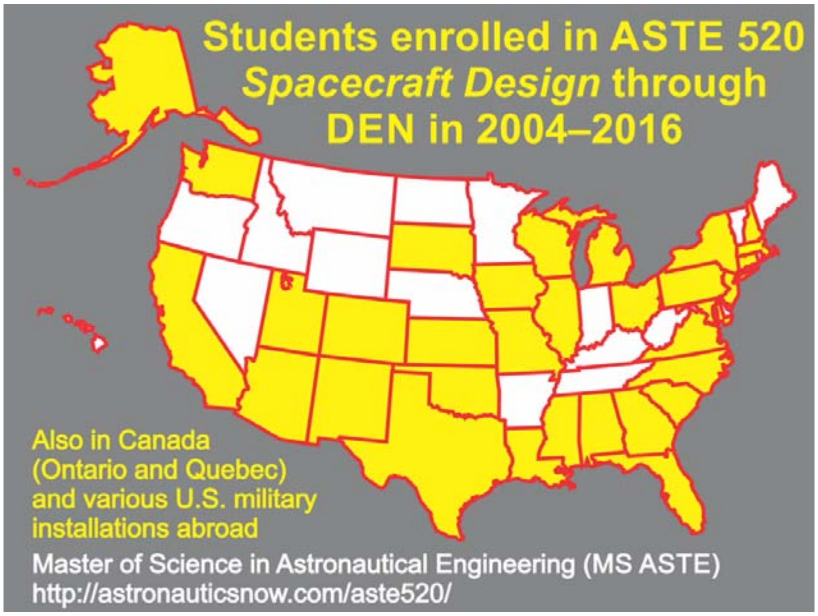
In addition to classroom, ASTE 520 *Spacecraft Design* is simultaneously offered through the USC Viterbi's Distance Education Network (DEN) and can be taken by students anywhere in the United States

ASTE 520 Spacecraft Design

ASTE-520
Spacecraft Design reaches students anywhere in the United States and abroad through the Distance Education Network (DEN)

Enrolled **1460+ students** during the last 15 years (2002-2016)

1700+ since 1996

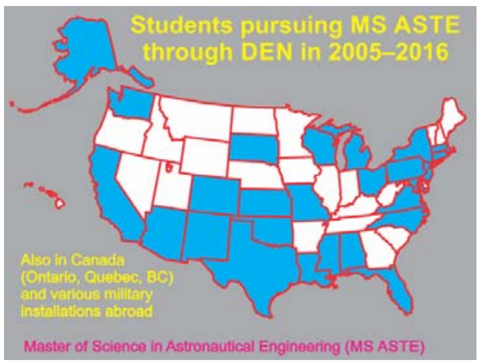


Astronautics on the West Coast

- ASTE 520 is a required core class for the USC graduate degree program in *astronautical engineering*.
  - ➢ Many students in other science and engineering graduate programs take ASTE 520 as technical elective
- USC Astronautics Program was established in 1994–1995
- Today, it is a comprehensive program

  that offers BS, BS Minor, MS, Engineer, and PhD degrees and Graduate Certificate in Astronautical Engineering

  ➢ Program history, focus, and organization is at **http://astronauticsnow.com/SpaceEducation/** (downloadable article from *Acta Astronautica* and AIAA paper)



Department of Astronautical Engineering (ASTE)

- USC established the ***Astronautics and Space Technology Division* (ASTD)** in August 2004 "to position the USC Viterbi School of Engineering to take full advantage of rapidly growing opportunities in space"
  - ➢ independent academic unit within the USC Viterbi School of Engineering operating as an academic department from day one (based on Astronautics specialization from mid-1990s)
  - ➢ 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)
- 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; download **http://astronauticsnow.com/mg_pubs/2014_gruntman_acta-astronautica_ms-aste.pdf**
or from http://astronauticsnow.com/SpaceEducation/

Department of Astronautical Engineering

- **USC Astronautics Program**

  Combines science and engineering fundamentals with highly specialized classes taught by astronautics adjunct faculty and part-time lecturers (top specialists in the trenches)

- MS ASTE web sites
  http://gapp.usc.edu/graduate-programs/masters/astronautical-engineering
  http://astronauticsnow.com/msaste/

- web site MS ASTE *Frequently Asked Questions FAQ*
  http://astronauticsnow.com/msaste/faq.html

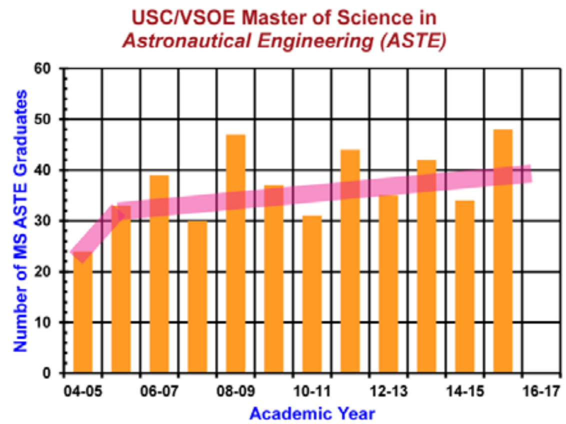
  Master of Science in Astronautical Engineering: Overview
  video (53 min): http://astronauticsnow.com/msaste/overview.html

- long-term class schedule —
  http://astronauticsnow.com/msaste/astd_ms_class_schedule.pdf

- always check with ASTE Student Adviser for updated class schedule

Some statistics

- 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)
- In AY 2011–2012, USC MS ASTE program accounted for **2.7%** of national enrollment in this broad aerospace/astronautical/aeronautical group



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

444 MS ASTE degrees awarded from 2004–2016; **38+** annually during last 11 acad. years

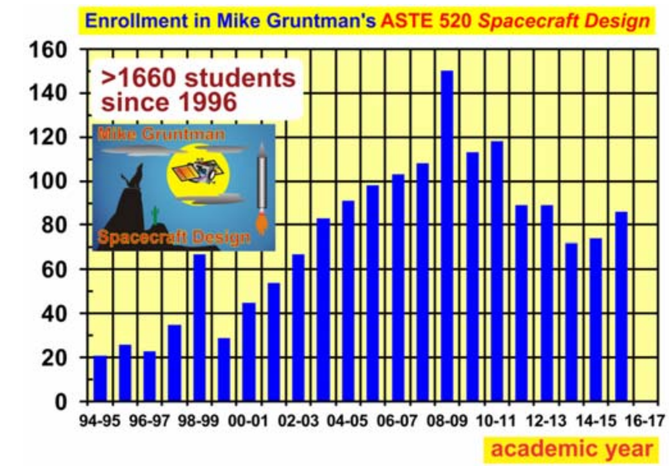
ASTE 520 – Spacecraft Design

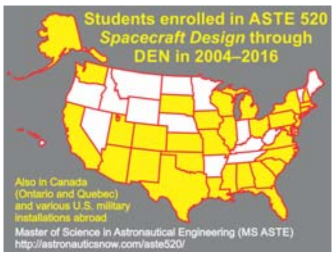
- **Prerequisite**
  Graduate standing in engineering or science
- **Class Notes**
  Class Notes are essential and mandatory for the course. Download Notes from the class web site at DEN (http://courses.uscden.net).
- **Class Procedure**
  Teaching will be done directly from the notes. It is advisable to bring appropriate materials to class.

ASTE 520
Spacecraft Design

Popular Course – Enrollment Dynamics

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





Enrollment depends on offering frequency, sabbatical leaves, and restrictions by other departments

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

Homework

- First HW assignments (1,2) due on **August 31, 2017.**
- There are 32 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 (≡ must be received by TAs) than **November 16, 2017** (inclusive).

  Late homework will be graded; the grade will be reduced by **50%**.

  No late homework submissions after November 16, 2017. ("No" means "No.")
- No "make up" (home)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 a few days after the due date.
- On-campus students submit homework in class. Online DEN students submit homework through http://courses.uscden.net .

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

- **Midterm Exam**
  12 October (Thursday), 2017
  7:00 – 9:00 p.m. (120 min)
  Instructor and TA will be present at 6:30 p.m.
  DEN will arrange proctoring for remote students

- **Final Exam**
  7 December (Thursday), 2017
  7:00 – 8:30 p.m. (90 min)
  Instructor and TA will be present at 6:30 p.m.
  DEN will arrange proctoring for remote students

- DEN rule: remote students from the Greater Los Angeles area must take exam on campus. Contact DEN directly if you have questions.

Grading

ASTE 520

Homework	**20%**
Midterm Exam	**40%**
Final Exam	**40%**

Exams are usually open-book, -notes, -….. No laptops.

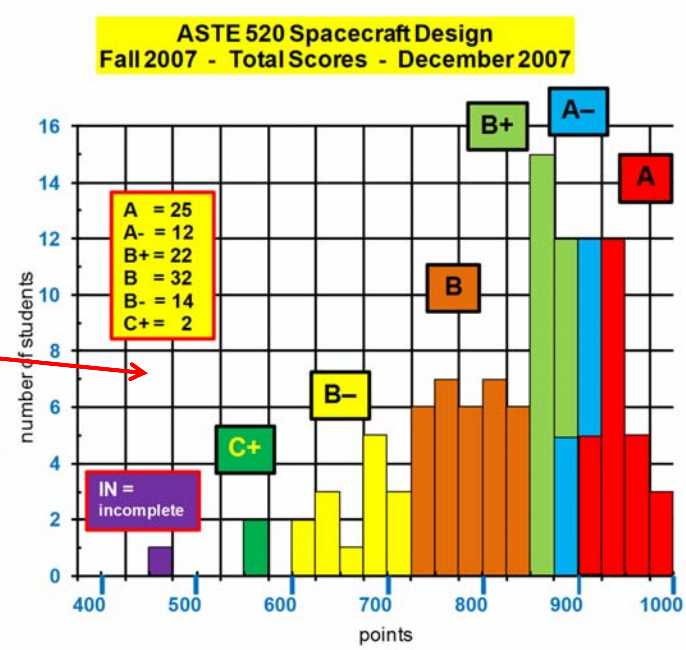
Typical Grade Distribution

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)



Organization of the Class

- Syllabus and schedule – flexible guidelines
- Class begins at 6:40 p.m. We have one 10–minute break during class.
- **Grading**: Teaching Assistant and Graders: TBA
- Questions and Complaints about grading
  - to be directed to TA
  - **only** if arbitration is necessary, contact the instructor
- **Communications with the instructor and TA**
  - office hours
  - telephone and e-mail
    - email to TA **or** instructor; copy to the other, **only** if necessary
  - Do not hesitate to call or see TA with questions about the class material, homework, etc.

Contact Teaching Assistant (TA)! TA is here to be bothered!

Office Hours – ASTE-520

- **Teaching Assistant's office hours**

  to be announced (TBA)

- **Instructor's office hours**

Tuesday	**3:00 p.m. – 3:45 p.m.**
	4:30 p.m. – 5:15 p.m.
Thursday	**3:00 p.m. – 4:30 p.m.**

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)
- **Religious Holy Days**
  - Discuss with instructor in advance conflicting schedules.
- **Questions**
  - Any aspect of astronautics and space exploration may be discussed
  - Fear not! Questions are welcome.
- **Academic Integrity**

  See the statement in the 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 and Textbook

Course Notes (>800 pages)

Mike Gruntman, *Spacecraft Design, ASTE-520 Notes*, Fall 2017

For your personal use only. Copyright protected.

Recommended text

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

or

***Space Mission Analysis and Design*, ed. W. J. Larson and J. R. Wertz,** Kluwer Academic Publ. and Microcosm, 3rd edition, 1999.

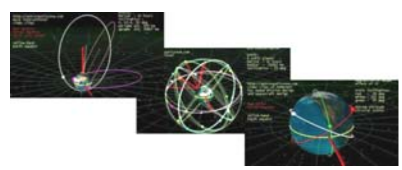
Please note that softcover editions of these books are much cheaper.

Spacecraft Design – Class Notes

- Class notes are mandatory and essential for the class
- Download class notes from the class web site at DEN at http://courses.uscden.net

  Password required (see slides 33–34)
- Teaching will be done directly from the notes – bring the required materials to the class
- Homework assignments are in the Class Notes
- Class and Homework submission schedules are in Section 00, Part 1
- Print the entire set of notes
  - Total number of pages > 800
  - Many students choose to print two slides/pages per sheet of paper
  - You can later print selected pages one page per sheet

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 embarrassment
- 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.uscden.net**

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

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

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.
- 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 University 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, 2010 (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/

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

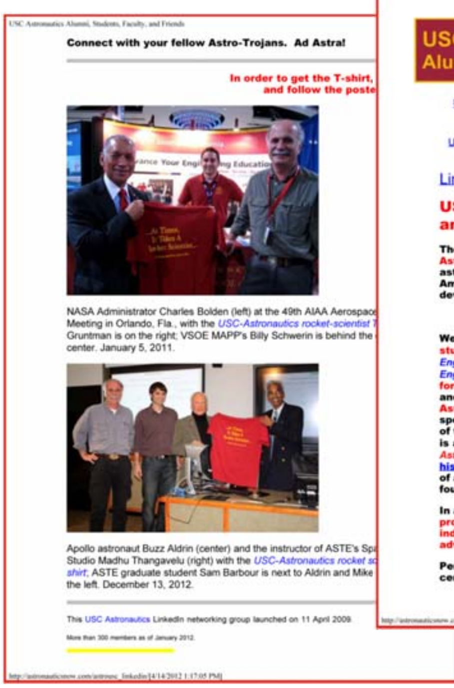
  AAS, AGU, APS, IEEE, OSA, SPIE, …. , ….

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 Astra!

In order to get the T-shirt, and follow the poste

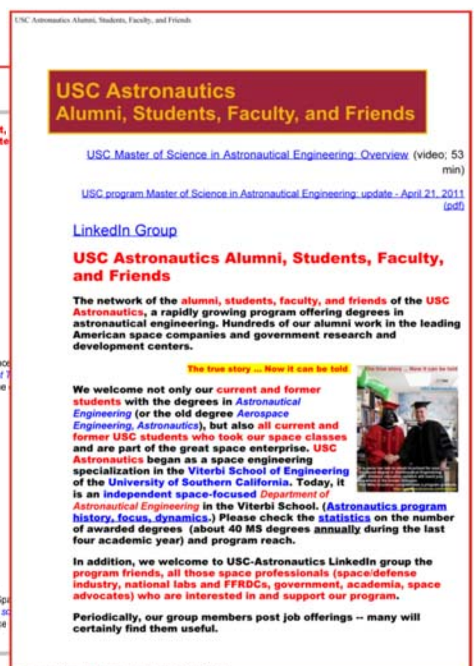
NASA Administrator Charles Bolden (left) at the 49th AIAA Aerospac Meeting in Orlando, Fla., with the *USC-Astronautics rocket-scientist T* Gruntman is on the right; VSOE MAPP's Billy Schwerin is behind the center. January 5, 2011.

Apollo astronaut Buzz Aldrin (center) and the instructor of ASTE's Sp Studio Madhu Thangavelu (right) with the *USC-Astronautics rocket sc shirt*; 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/[4/14/2012 1:17:05 PM]



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/[4/14/2012 1:17:05 PM]

USC Astronautics

USC Astronautics networking group launched in April 2009

>600 members (as of Jan 2016)

http://astronauticsnow.com/astrousc_linkedin/

ASTE 520 on DEN

- **Lecture webcasts**

  All lectures are available through Distance Education Network DEN for all students enrolled in class during the entire semester

- **PC or Mac**

  DEN streams course videos using Microsoft Windows media encoders and servers. While streaming windows media files are supported by both the latest Mac and PC operating systems, using a Windows based system will usually provide a better experience. Additionally, DEN has recently added video download capabilities using Microsoft's Digital Rights Management supporting Windows operating systems.

On-Campus and DEN Instructions

- On all homework pages, put your name and course number ASTE-520
- On-campus (non-DEN) students must submit their homework in class; they will receive graded homework also in class
  - non-negotiable rule
- 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 class at the convenient time through webcast.
- Final and Midterm exams are held on campus for students in the Los Angeles area (no exceptions). Outside this area, the exams are arranged at remote sites (contact DEN).
- If you absolutely have to be on a business trip during the exam – contact the instructor in advance.

All Students – Homework

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

GAPP/DEN – Student Resources

- VSoE Graduate Programs – http://gapp.usc.edu
- VSoE Distance Education Network (DEN) – Current Students
  http://gapp.usc.edu/graduate-programs/den/students
- Login to the class web site at DEN, homework submissions, etc. at
  http://courses.uscden.net
- GAPP/DEN resources – http://gapp.usc.edu/students/masters
  - Print names and telephone numbers of DEN contact persons
  - Use it! Do not be shy!
  - Call them!
  - E-mail them!
  - They are here to help!
  - They will be delighted to hear from you – trust me

Survey and Password

- E-mail the survey (next slide) to the instructor (mikeg@usc.edu) **from August 11, 2017** as a plain text in your message (do not attach as an MS Word or PDF file) with the **subject line ASTE520 Survey**. (Note that the instructor has a heavy biz travel schedule in August 2016 – expect 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, AerospaceE, MechanicalE, ElectricalE, SystemE, Physics, Astronomy, …)
3. Degree sought (MS, PhD, Certificate, BS, Progressive 4+1, …) and field (AstroE, EE, ME, CompE, AE, CivilE, ChE, Phys, Chem, …)
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, VeryCoolRockets.com, etc., …)
5. Location of your place of work: city, state
6. Telephone
7. E-mail
8. 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 μm
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	=	$1.013\,25 \times 10^5$ N/m^2	=	1.013 25 bar
1 psi	=	$6.894\,76 \times 10^3$ N/m^2	=	6.805×10^{-2} atm

Units and Constants

Electron charge (e)	=	1.6022×10^{-19} C
Electron-volt (eV)	=	1.6022×10^{-19} J
Atomic mass unit (amu)	=	1.6605×10^{-27} kg
Boltzmann constant (k_B)	=	1.38065×10^{-23} J K^{-1}
Stefan-Boltzmann constant (σ_{SB})	=	5.6704×10^{-23} W m^{-2} K^{-4}
Astronomical Unit (AU)	=	1.496×10^{11} m
Earth equatorial radius (R_e)	=	6 378.14 km
Gravitational constant (G)	=	6.6726×10^{-11} m^3 kg^{-1} s^{-2}
Free fall acceleration (g)	=	9.80665 m/sec^2
μ_{EARTH}	=	3.9860×10^{14} m^3/sec^2
μ_{SUN}	=	1.3271×10^{20} m^3/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, Giga, ...
- Conversion coefficients and physical constants (*G, c, h, k, ...*) 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	Α	alpha	ι	Ι	iota	ρ	Ρ	rho
β	Β	beta	κ	Κ	kappa	σ	Σ	sigma
γ	Γ	gamma	λ	Λ	lambda	τ	Τ	tau
δ	Δ	delta	μ	Μ	mu	υ	Υ	upsilon
ε	Ε	epsilon	ν	Ν	nu	φ	Φ	phi
ζ	Ζ	zeta	ξ	Ξ	xi	χ	Χ	chi
η	Η	eta	ο	Ο	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			