ASTE 520 Spacecraft Design

Spring 2009

Mike Gruntman

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

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://den.usc.edu).

  password required (see Slides 31–32)
- Teaching will be done directly from the notes – bring the required materials to the class
- Files for the first class meeting on January 16, 2009:

  2009_MG_SCD_00_part_1_no_pswd.pdf

  2009_MG_SCD_00_part_2_no_pswd.pdf (this presentation)

  2009_MG_SCD_01.pdf (self study for homework)

  2009_MG_SCD_02.pdf

Attention: read this section of Class Notes for rules

Contents – ASTE 520

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.

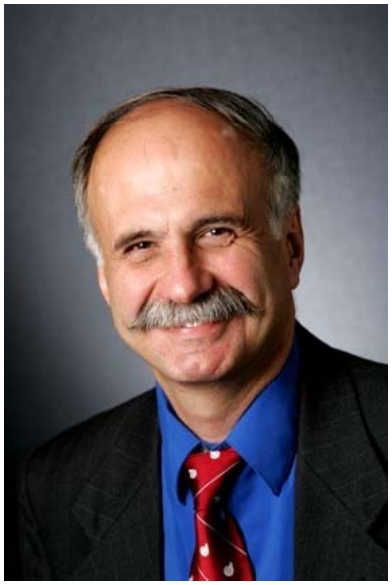
Instructor

Mike Gruntman

Professor of Astronautics

Astronautics and Space Technology Division

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



- detailed biographical sketch in Section 00, Part 1
- communications on the first-name basis most welcome
- URL http://astronauticsnow.com/MikeGruntman/
  http://astronautics.usc.edu

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 and Systems E, Nuclear E, Chemical E, Computer E, …….

  and/or

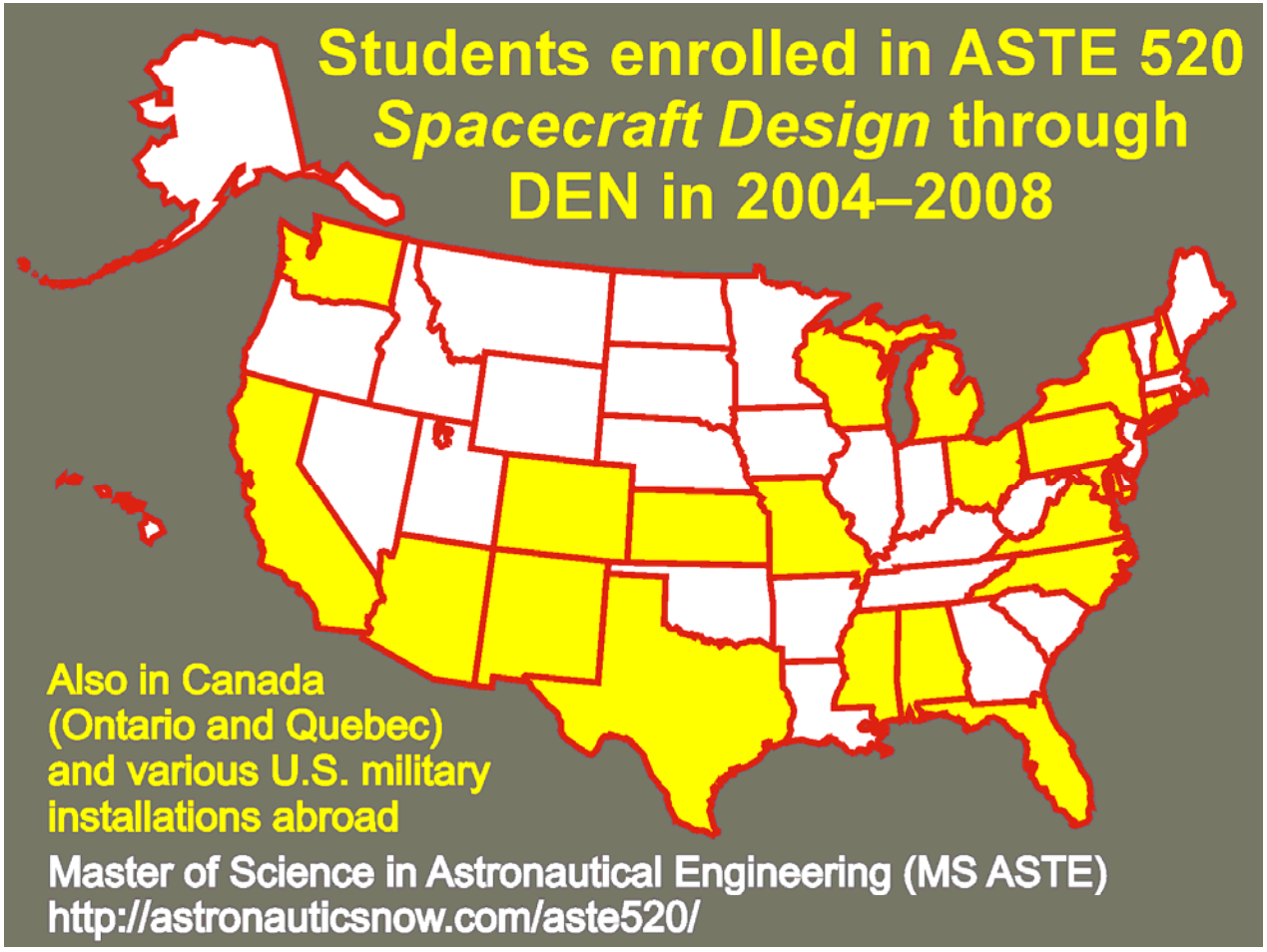
- **If you work or plan (want) to work** in the space or defense industry or in government space research and development centers (NASA, Air Force, DOE, NOAA, …) or space mission operations and control centers

This course – ASTE 520 – IS FOR YOU

ASTE 520 *Spacecraft Design* is 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* accessible to students anywhere in the United States through the Distance Education Network (DEN)



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/

    (includes downloadable papers at AIAA and ASEE conferences)

Astronautics and Space Technology Division

- 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”
  - See program history at http://astronauticsnow.com/SpaceEducation/
- ASTD is an independent academic unit within the USC Viterbi School of Engineering and functions in a manner similar to an academic department
- ASTD assumed charge of all former degree programs and courses in *aerospace engineering (astronautics)*, postcode AEAN
  - USC approved in May 2005 new degree programs in *astronautical engineering* (postcode ASTE) and discontinued programs in *aerospace engineering (astronautics)*
- Today, ASTD offers BS, BS Minor, MS, Engineer, and PhD degrees and Graduate Certificate in *astronautical engineering* (postcode ASTE)
- ASTD is responsible for programs in astronautics and space technology at USC, concentrating on meeting the educational and research needs of interest to the space and defense industries, government research and development centers, and academia

Astronautics and Space Technology Division

- 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)

- ASTD web site — http://astronautics.usc.edu

- Web site *Frequently Asked Questions FAQ MS ASTE*

  http://astronauticsnow.com/MSASTE/

- Long-term class schedule — http://astronauticsnow.com/MSASTE/

- Always check with ASTD Student Affairs for updated class schedule

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://den.usc.edu).

- **Class Procedure**

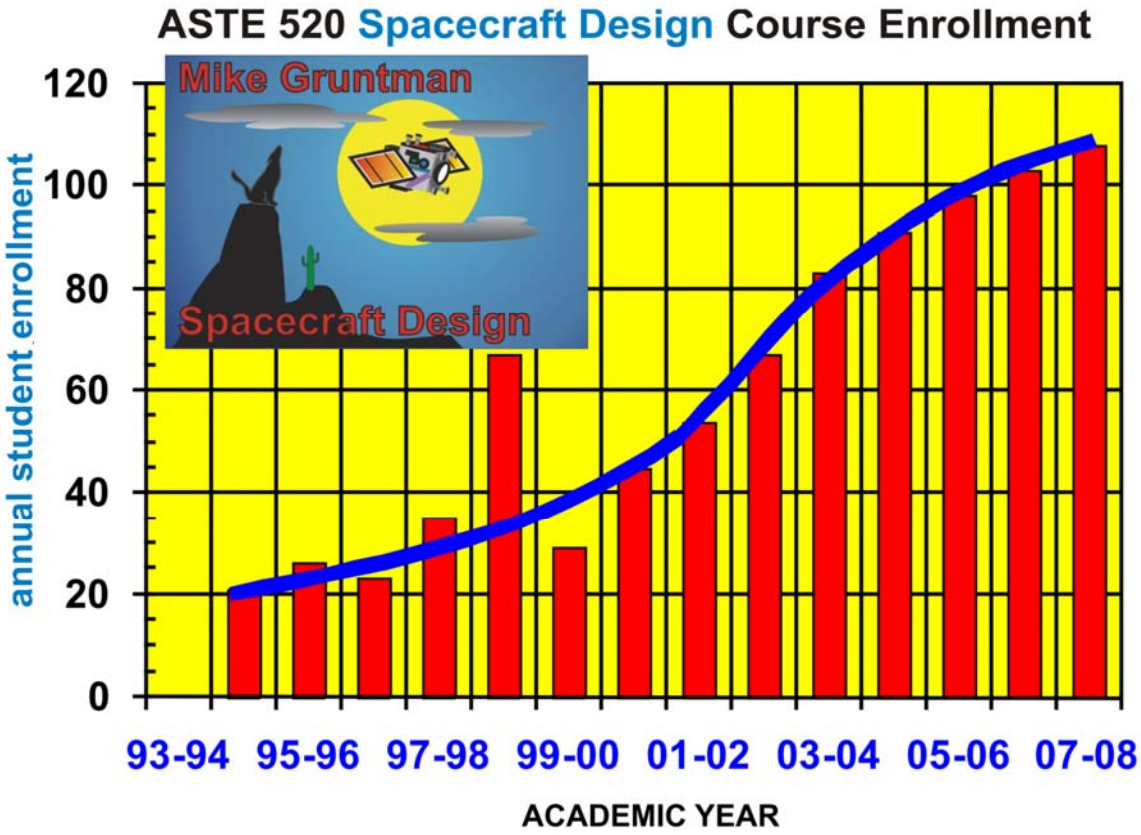
  Teaching will be done directly from the notes. It is advisable to bring appropriate materials to class.

ASTE 520
Spacecraft Design

Popular Course – Enrollment Dynamics

ASTE 520 students hailed:

- **in Spring 2005 from 14 States of the Union**
- **in Spring 2006 from 10 States**
- **in Spring 2007 from 12 States**
- **In Fall 2007 from 11 States**



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.

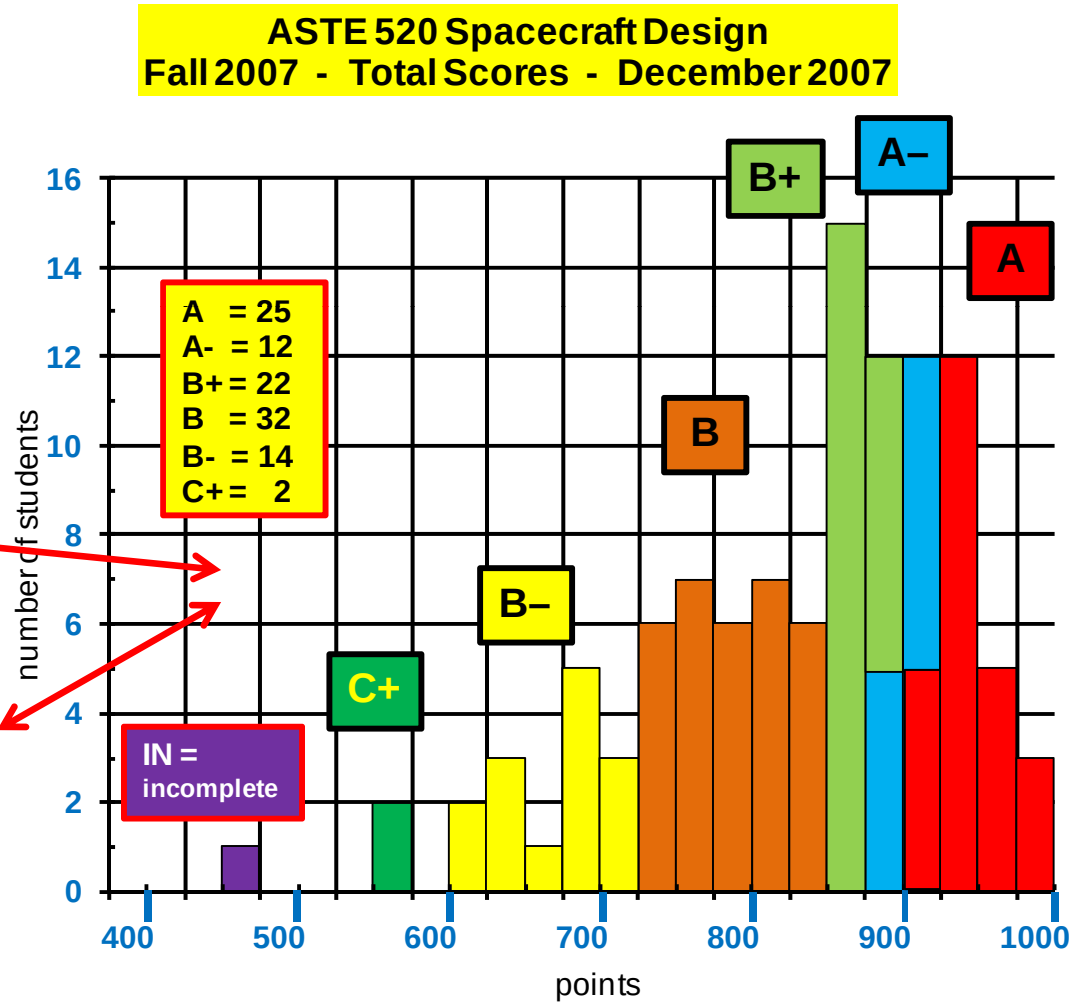
Typical Grade Distribution

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)



Homework

- First HW assignments (1,2) due next week – ! – on January 23, 2009.
- There are 34 homework assignments. Due as scheduled (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 April 24, 2009 (inclusive).

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

  No late homework submissions after 24 April. ("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 are posted at the class web site at DEN (http://den.usc.edu).
- Solutions will be posted, usually a few days after the due date, at the class web site at DEN (http://den.usc.edu).

Exams and Grading

- **Midterm Exam**
  6 March (Friday)
  5:00 – 7:00 p.m. (120 min), in class
  Instructor and TA will be available at 4:30 p.m.
  DEN will arrange proctoring for remote students

- **Final Exam**
  8 May (Friday)
  5:00 – 6:30 p.m. (90 min) , in class
  Instructor and TA will be available at 4:30 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.

Organization of the Class

- Syllabus and schedule – flexible guidelines
- Class begins at 5:00 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; add a 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

- **Teaching Assistant's office hours**

  to be announced (TBA)

- **Instructor's office hours**

  Tuesday 3:00 p.m. – 5:00 p.m.

  Friday 2:30 p.m. – 4:00 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,* Spring 2009

  For your personal use only. Copyright protected.

- **Required text**

  ***Space Mission Analysis and Design,* ed. W. J. Larson and J. R. Wertz,** Kluwer Academic Publishers and Microcosm, 2nd or 3rd editions.

  In addition to the USC bookstore and on-line booksellers (Amazon, B&N, etc.), this book (softcover ~$50–60) can be purchased **directly and conveniently** from the publisher – **http://astrobooks.com** .

Spacecraft Design – Class Notes

- Class notes are mandatory and essential for the class
- Download class notes from the class web site at DEN (http://den.usc.edu). Password required (see slides 31–32).
- Teaching will be done directly from the notes – bring the required materials to the class.
- Homework assignments are in the Class Notes
- Class schedule and Homework submission schedule 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 – free download 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://den.usc.edu**
Public (permanent) **class web site:**	**http://astronauticsnow.com/aste520/**
Also, frequently asked questions:	**http://astronauticsnow.com/msaste/**

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.
- V. A. Chobotov, *Orbital Mechanics*, AIAA, 1991.
- P. Fortesque and J.Stark, *Spacecraft Systems Engineering*, John Wiley and Sons, 1995.
- M. D. Griffen and J. R. French, *Space Vehicle Design*, AIAA.
- M. Gruntman, *Blazing the Trail: The Early History of Spacecraft and Rocketry*, AIAA, 2004.
- S. J. Isakowitz, *International Reference Guide to Space Launch Systems*, AIAA, 1991.
- 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 and Sons, 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.
- G. P. Sutton, *Rocket Propulsion Elements*, John Wiley and Sons, 1986.
- 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.
- J. R. Wertz, ed., *Spacecraft Attitude and Determination Control*, Kluwer, 1978.

Many, many, many other books – see instructor's web site

http://astronauticsnow.com/AstroBooks/

Professional Societies

- 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, …. , ….

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.**

Contact DEN

- DEN web site http://den.usc.edu
- Instructions on homework submissions are at http://den.usc.edu
- The list of DEN contacts is at http://den.usc.edu
  - print the page with the 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) after **January 04, 2009** as a plain text in your message (do not attach as an MS Word or PDF file) with the subject line *ASTE520 Survey*
  - 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 as 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. Degrees attained: university and field (e.g., AerospaceE, ME, EE, Phys, …)
3. Degree sought (MS, PhD, Certificate, …) and field (AstroE, EE, ME, CompE, AE, CivilE, ChE, Phys, Chem, …)
4. Are you a full-time student? Or, do you work full 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. Your (place of work) location (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	=	1.6605×10^{-27} kg
Astronomical Unit (AU)	=	1.496×10^{11} m
Earth equatorial radius	=	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

You must be confident in juggling units: *meter, mile, nautical mile, astronomical unit, pound, foot, tor, Newton, radian, ...*

Conversion coefficients can be found in many publications (e.g., *AIAA Aerospace Design Engineers Guidebook, etc*).

A guide to the use of the [metric] International System of Units (SI) can be found at the *National Institute of Standards and Technology* (NIST) web site

http://physics.nist.gov/Pubs/SP811/sp811.html

Make a copy of the pages with the conversion coefficients, or prepare such a list yourself, and attach it to your notes. Such a list will be exceptionally useful (and time-saving) for working on the homework assignments and exams.

Units and Constants

- Prefixes

  kilo, nano, deka, femto, Giga, ...

- Physical constants

  G, c, h, k, ...

- Compile a separate list of physical constants as the class progresses (will be useful!).

- Many physical constants can be found at the NIST web site

  http://physics.nist.gov/cuu/Constants/index.html