Department of Astronautical Engineering
aste-classes.usc.edu

ASTE 331a, Fall 2023
Spacecraft Systems Engineering

3 units
Lectures: Fridays 12:30 – 3:20 PM, In-Class (SOS B2) and Online
Zoom Link: https://usc.zoom.us/j/... (Meeting ID 967 9516 1476)
All lectures are recorded and charts will be available prior to the start of class.

Instructors

Jim Chase, chasejam@usc.edu

Office Hours: By appointment
Preferred times are after class, very early/late on weekdays (M-Th), or weekends (9am-5pm)
Zoom Link: https://usc.zoom.us/j/5539298026 (Meeting ID 553 929 8026)

TAs: TBD TBD TBD

Welcome to ASTE 331a! By now, most of you will have completed your lower division coursework and have achieved an understanding of the math and physics principles that form the basis of astronautics (or more commonly referred to as 'rocket science'). Your next step is to dive into this class, where designing a spacecraft goes from a lofty idea that sounds exciting to the reality of actually understanding the complex interdependencies of how individual subsystems form a functioning spacecraft. While I can't promise you this will be easy, I can assure you that it is achievable and, in partnership, you will develop a more comprehensive understanding of complex engineering designs and the value of systems engineering – concepts applicable across many fields.

As your guide for this adventure, I am a part-time lecturer coming from the NASA Jet Propulsion Laboratory. I have been at JPL for just over twenty years, where I have supported a diverse assortment of missions, including the conceptual designs for lunar landers and asteroid sample return missions and the realized missions of the Mars Phoenix Lander and the Curiosity Rover. I am looking forward to spending the semester with all of you and am committed to helping you achieve the course objectives. Below you will find the details of this course and my expectations for our time together.

Course Description

This course provides a comprehensive introduction to space systems and the environment in which they operate, including the typical spacecraft subsystems of propulsion, attitude control, control and data handling, software, telecommunications, electrical power, mechanical, and thermal control. For each of these areas, we will discuss the governing physics principles and their application via real-world case studies and design problems. You will learn industry best practices and use some of the most common applications, such as Excel, Matlab, and/or Python. This knowledge will provide a critical foundation for both learning about integrated space systems and exploring the individual disciplines of astronautics in greater depth.

Note that ASTE 331a is the first semester of a two-semester course. The second semester (331b) encompasses space systems engineering and the design process, including a spacecraft design project.

Prerequisite: ASTE 280 – Foundations of Astronautical Engineering
Corequisite: PHYS 153 – Fundamentals of Physics III: Optics and Modern Physics
Recommended Preparation: Proficiency in Win/Unix OS & Microsoft Office, introductory knowledge of Matlab

Learning Objectives

After taking this course, students will understand:

- The fundamental physics of spacecraft systems
- The relationship between mission requirements and system performance requirements
- How to design subsystems to meet performance requirements
- Balancing design tradeoffs at the subsystem-level
- Best practices and commonly used tools within the aerospace industry

Description and Assessment of Assignments

The table below describes the key course components that are considered for grading. Given the nature of this year's course, the emphasis of participation has been increased to promote overall engagement with the class via in-person/virtual lectures, Piazza, study groups, and office hours. Also, to encourage reading and discussion, there are weekly quizzes that are discussed and submitted via small groups (including Zoom breakout rooms for those virtually attending). While the intent is to follow the approach described below, it is flexible and may evolve over the course of the semester with changes communicated in class.

Please note that this format is structured to benefit the overall class, but if there are concerns, please let us know, and we can work to accommodate them depending on the circumstance.

<table>
<tr><th colspan="2" rowspan="2">Type</th><th rowspan="2">Description</th><th colspan="3">Grading</th></tr>
<tr><th>%</th><th>Approximate Criteria</th><th>Approach</th></tr>
<tr><td rowspan="5">Participation</td><td>Lectures</td><td>Weekly class lectures, including attendance and participation</td><td rowspan="5">15%</td><td>• ≥ 90% attendance
• ≥ 1 question, answer, or comment per lecture (full class)
• ≥ 50% of classes in-person or with video enabled</td><td rowspan="3">End-of-month self-assessments that are reviewed, audited, & graded.

Note that participation can be traded across categories (eg, a weekly study group can offset not posting to Piazza).</td></tr>
<tr><td>Piazza</td><td>Posting questions, answers, or comments to online threads</td><td>• ≥ 1 post every 2 weeks in Piazza
• ≥ 90% of other posts read</td></tr>
<tr><td>Small Groups</td><td>Participating in study groups or instructor/TA office hours</td><td>• ≥ 1 meeting every 2 weeks</td></tr>
<tr><td>Feedback Review</td><td>Review feedback provided by the professor/TA</td><td>• 100% of feedback read, understood, and applied where relevant</td><td rowspan="2">Blackboard generates an individual submission status, which will be used.</td></tr>
<tr><td>1-min Eval</td><td>Anonymous submission of weekly 1-min evaluation w/feedback on the course via Blackboard.</td><td>• ≥ 90% weekly submission rate</td></tr>
<tr><td rowspan="2">Homework</td><td>Reading</td><td>Weekly reading assignments and quizzes (via small groups) in advance of the corresponding lectures.</td><td>5%</td><td rowspan="4">Assignments will vary, but here are the typical criteria:
• On-time & complete submission
  ○ Submitted on time?
  ○ All instructions followed?
• Technical accuracy
  ○ Are there any errors?
  ○ Are existing questions/issues highlighted?
• Communication & formatting
• Is the assignment well organized and easy to review?</td><td>Instructor/TA grades each group submission.</td></tr>
<tr><td>Problem Sets</td><td>Weekly problem sets that will be completed in Excel and other applications.</td><td>50%</td><td rowspan="3">Instructor/TA grade individually.</td></tr>
<tr><td rowspan="2">Exams</td><td>Mid-Term</td><td>Exam to evaluate understanding of weeks 1-7</td><td>15%</td></tr>
<tr><td>Final Exam</td><td>Exam to evaluate overall course understanding</td><td>15%</td></tr>
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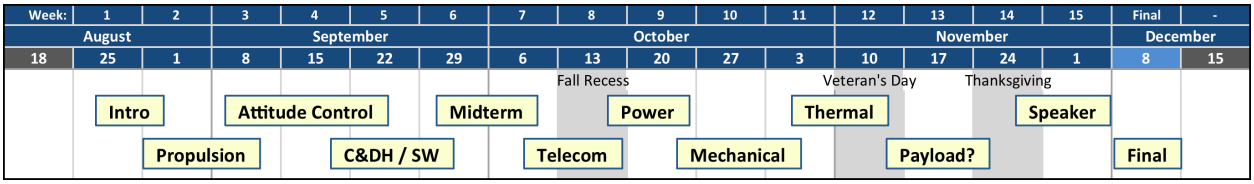
Approximate Schedule

The times and topics given below are approximate, and the list may change as the semester progresses. We will see how things go and take more or less time on each topic as seems appropriate. Note that USC has specified three Fridays as "no class" days, which presents a slight logistical challenge given that our class is on Fridays and the underlying intent is 1 week (rather than 3 weeks) of no classes. At the end of each lecture, I will provide a more detailed schedule that will cover the proceeding 3-4 weeks, including assignment due dates.



Second-Semester Topics: Mission Design & Navigation (refresher), Systems Engineering, Requirements, Verification & Validation, System Integration and Test, and System-Level Analyses, including block diagrams, fault protection, mass, power, data, and cost. There will also be a design project that combines your knowledge from both semesters.

Assignment Format, Timeliness, & Feedback

All assignments are expected to be grammatically correct with clear and readable formatting that allows the audience to quickly access, understand, and assess the content. To help with this objective, I will provide a course handout, "Writing, Presentation, and Analysis Best Practices," that should be considered when submitting all assignments. The expectation is that you will complete assignments prior by Thursday end-of-day unless otherwise specified. If there is a delay, please communicate with me in a timely manner and, in writing, with an estimated completion date. If your requests are in advance, infrequent, and you submit by your estimated completion date, no points will be deducted.

Important: Please begin the assignments and ask new (& review existing) questions via Piazza several days in advance, as early questions will help the overall class, whereas last-minute ones can cause confusion and/or unnecessary rework. In this context, I will provide timely and detailed answers to those submitted ≥ 1 day in advance, whereas my answers to later questions are likely to be more vague and/or require office hours.

Feedback on assignments will vary depending on several factors. Historically, I have provided more detailed written feedback early, which gradually diminishes over the course of the semester. I typically augment this with individual office hours, where we can step through assignments either before or after submission. Given this semester's large class size, however, please consider setting up small group zoom sessions in lieu of individual office hours, where I can more efficiently answer questions and provide detailed feedback.

Note that when written feedback is provided, the expectation is that you'll review and incorporate this feedback into future assignments. This is especially relevant for simpler updates (eg, formatting, file name conventions, table structures), which visibly demonstrate that you've read and applied the feedback provided.

Collaboration

Across the engineering discipline, collaboration is essential to the design and development of new products. Therefore, it is critical that you develop the requisite skills for working in groups without compromising your academic integrity or, more specifically, "presenting someone else's ideas as your own." Here are my guidelines that should help you navigate this boundary:

- I strongly encourage participating in study groups, including sharing ideas/concepts, reviewing others work, and providing helpful feedback.
- If you create a product (eg, idea, template, algorithm, etc.) that is not a direct objective of an assignment or exam, you are encouraged to share it with others.
- If/when you receive such a product, please provide a note that acknowledges the contribution of the author. Additionally, if the product is significant in your resulting work (eg, set of algorithms), please annotate it to show that you understand and agree with the logic. Note that in a highly collaborative environment, it is this type of iterative review and discussion that enhances (rather than compromises) intellectual understanding.

Grading Scale

Assignments/tests are graded per the criteria described earlier on either a 10-point or 100-point scale depending on the magnitude of the submission, where ≥ 90% is excellent (~A), 80-90% is good (~B), 70-80% is fair (~C), 60-70% needs improvement (~D), and < 60% is poor (~F).

For the cumulative midterm and final grades, the individual components are weighted as described in the prior table to produce an overall score (0-100). These resulting scores will generally result in letter grades that correspond with the original grading scale (i.e., ≥ 90 = A, 80-90 = B, etc.), but I may tailor this scale to better reflect statistically significant peer groups within the class consistent with USC policy. Note that as part of my grading, I regularly review students performing at the top, median, and bottom of the class to ensure that their resulting grades are consistent with their knowledge relative to course expectations.

Note that "+" and "-" grades will be assigned to ± 3 points across each letter boundary (e.g., 90-93 = A-, 87-90 = B+). While USC does not recognize an A+ (≥ 97%), I will note this grade and may refer to it in letters of recommendation.

Required Readings and Supplementary Materials

The textbooks referenced this semester are:

1. **Required:** Space Mission Engineering: The New SMAD, James R. Wertz, David F. Everett and Jeffery J. Puschell, eds. Microcosm, 2011. ISBN 978-1881883159.
2. **Optional:** Vincent L. Pisacane, Fundamentals of Space Systems, 2nd ed. Oxford, 2005. ISBN 978-0195162059.

SMAD is a great reference with significant information from actual missions, which you are likely to use throughout the course and your career. However, its explanations are a bit terse, and therefore I'll cover many of the required topics via weekly charts that will hopefully provide more helpful explanations. Additionally, Pisacane is a traditional textbook that defines concepts starting from first principles. I'll cover the essential information in class, but this book might be useful if you are interested in more depth or context behind the material.

Additionally, there will be supplementary materials that will be announced in class and provided via Blackboard.

Online Course Materials

Blackboard: This is the online site for this course. The primary features used are posting announcements, submitting assignments, and providing access to course materials. It is recommended that you set the notification settings to ensure prompt updates via email or text.

- **Contents:** Lecture Charts & Recordings, Class Assignments, Reference Material, Templates, etc.
- **Link:** https://blackboard.usc.edu/...
- **Important:** I will generally keep the assignments page up-to-date – please bookmark it in your browser

Piazza: This is a supplemental online site that is used as a forum for online discussions. Please use this site (rather than email to me) for questions.

- **Link:** https://piazza.com/class/...
- **Important:** There may be material posted here that is essential to completing the assignments

Software Used

The following software applications are intended for use in this two-semester course, although specific applications of them will vary depending on the progress of the course.

Microsoft Office (Excel, Powerpoint, Word): This tool suite is critical across the aerospace industry with wide use to support a variety of applications. In 331ab, we will be extensively using Excel, occasionally using Powerpoint, and rarely using Word. Please ensure that you have this software and/or easy access to it.

Virtual Desktop Infrastructure (VDI): Viterbi MyDesktop is the current site for virtual computing resources available to students of select engineering classes. It is intended to provide students with access to engineering and scientific software packages whose licensing terms prohibit their installation on personally owned computers, involve complex installation procedures, or require elevated hardware resources for satisfactory experience. 331a has been granted access to both general and enhanced VDI.

- **General VDI:** STK, Matlab, Python
- **Enhanced VDI:** Thermal Desktop, NX
- Access provided until the end of the semester.
- Technical Support is available by via engrhelp@usc.edu. When submitting questions, please provide as much information as possible, including name, USC email, class, professor and a description of the issue.
- **Link:** https://viterbiit.usc.edu/instructional-support/

Matlab: Matlab couples mathematics and graphics libraries with a C-like language that uses vector and matrix syntax to produce high-fidelity numerical solutions and graphics. It is commonly used within the aerospace industry, particularly with respect to orbital mechanics, dynamics and controls simulations, optics, and/or other performance analyses.

Python: Python is an interpreted, object-oriented, high-level programming language that is often used for "scripting" and connecting existing applications together. Its simple, easy-to-learn syntax emphasizes readability and its support of variety of modules, allows it to be customized for individual applications. It used in many industries, including Aerospace, due to the increased productivity that it provides.

ANSYS STK (Systems Toolkit): A package for setting up, simulating, and visualizing the operation of space missions. Launch, orbits and station keeping, attitude dynamics and control, communications, and ground station operations can all be simulated. It is available via both VDI and the ASTE department, which has a site license courtesy of Analytical Graphics Inc. (AGI). For installation and licensing of STK on your local machine, see http://aste-classes.usc.edu/stk.

NX (Siemens): A package for computer-aided design (CAD) and analysis. It is used in AME coursework, so you may already have it installed. In this class, NX is used for structural analysis, including resonant vibration frequencies.

Thermal Desktop: A package for computer-aided mechanical and thermal analysis of structures. This software is more likely to be used in the second semester for analysis of the end-to-end spacecraft.

Statement on Academic Conduct and Support Systems

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 Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. 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.

Additionally, I would like to add that your conduct and reputation are critical to our class, USC, and your future career. Throughout the semester, you will have many opportunities (especially in our virtual activities) to demonstrate your conduct. In my experience as both an instructor and engineering manager, I know the vast majority of you take this responsibility seriously. However, I have also seen a handful of past infractions, such as reporting inaccurate participation metrics, misrepresenting your work, and accessing solutions prior to submitting assignments. Please avoid these and others, which often standout when we grade and/or audit your work. Note that active collaboration (which increases your knowledge) is very much encouraged – see earlier section.

Support Systems

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime. Provides overall safety to USC community. dps.usc.edu