Department of Astronautical Engineering
aste-classes.usc.edu

ASTE 331a, Fall 2021
Spacecraft Systems Engineering

3 units
Lectures: Fridays 12:30 – 3:20 PM, In-Class (KAP 156) & Online
Zoom Link: https://usc.zoom.us/j/... (Meeting ID 922 1412 1356)
All lectures are recorded and charts will be available prior to the start of class.

Class updates with respect to COVID-19

- *I will work to ensure that the online & in-class experiences are similar*
- *I encourage you to attend our weekly lectures online, including the 1st day where I expect attendance will be higher.*
- *Office hours that are set-up after class can be in-person/outside or virtual. Other times will be virtual via Zoom.*
- *In the event that I am on travel or otherwise unavailable, I may pre-record a lecture for our class period.*

Instructors

Jim Chase, chasejam@usc.edu

Office Hours: By appointment
Preferred times are after class, weekdays (M-Th), early (6-8am), or weekends (8am-5pm)
Zoom Link: https://usc.zoom.us/j/5539298026 (Meeting ID 553 929 8026)

TA: Queenique Dinh

Office Hours: 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 nearly 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

Introduction to spacecraft subsystems, including propulsion, attitude dynamics and control, structures, communications, power, and thermal control, along with the space environment. Systems engineering as applied to spacecraft.

Note that ASTE 331a is the first semester of a two-semester course. The second semester (331b) will encompass 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 the two-semester course, students will:

- Understand the fundamental physics of spacecraft systems
- Understand the relationship between mission requirements and system performance requirements
- Design subsystems to meet performance requirements
- Make design choices taking system tradeoffs into account
- Understand the steps in performing a complete spacecraft system design

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 small group 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 this approach, it is flexible and may evolve as appropriate 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 specific concerns, please let me know, and we can discuss how they can be accommodated depending on the circumstance.

Type		Description	Grading		
			%	Approximate Criteria	Approach
Participation	Lectures	Weekly class lectures, including attendance and audio/video participation	15%	• ≥ 90% attendance (in-class/virtual) • ≥ 1 question, answer, or comment per lecture (full class) • ≥ 50% of classes in-person or with video enabled	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).
	Piazza	Posting questions, answers, or comments to online threads		• ≥ 1 posts/week in Piazza • ≥ 90% of other posts read	
	Small Groups	Participating in in-class/virtual study groups or instructor/TA office hours (outside of classes)		• ≥ 1 meeting every 2 weeks	
	1-min Eval	Submission of weekly 1-min evaluation with feedback on the course		• ≥ 90% weekly submission rate	End-of-class handouts or online Blackboard submission are collected.

Homework	Reading	Weekly reading assignments and quizzes (via small groups) in advance of the corresponding lectures.	5%	Assignments will vary, but here are some 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?
					Instructor/TA grades each group submission. No quiz the first week.

	Problem Sets	Weekly problem sets that will typically be completed in Excel (mostly) and other mediums.	40%		Instructor/TA grade individually.
Exams	Mid-Term	80-min exam to evaluate understanding of weeks 1-7	20%		
	Final Exam	120-min exam to evaluate overall course understanding	20%		

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 generally be followed when submitting all assignments. *(Creating this handout is a goal and depends on available time, but feel free to check-in on status.)*

The expectation is that you will complete assignments prior to each Friday class 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 am setting aside time early Mon-Wed mornings to provide more timely and detailed answers, but I will still try to respond to all questions whenever you have them.

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 have typically augmented this with individual office hours, where we would step through assignments either before or after submission. This semester, however, will be more challenging since the size of the class is twice that of prior semesters. In this context, consider setting up small group zoom sessions in lieu of individual office hours, where I can answer questions and provide more detailed feedback for those of you interested.

Note that when written feedback is provided, the expectation is that you'll review and incorporate into future assignments. This is especially relevant for items such as formatting, file name conventions, table structures, etc.

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 citation 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

Weekly assignments (including self-assessments, reading quizzes, and problem sets) are graded per the criteria described earlier on a standard 0-10 scale, where ≥ 9 is excellent (~A), 8-9 is good (~B), 7-8 is fair (~C), 6-7 needs improvement (~D), and < 6 is poor (~F). The midterm and final exam are graded in the same fashion, but against a 100-point scale.

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 (ie, ≥ 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 "+" and "-" grades will be assigned to ± 3 points across each letter boundary (eg, 90-93 = A-, 87-90 = B+).

Required Readings and Supplementary Materials

There is one required textbook and one optional textbook:

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 a better explanation. Additionally, Pisacane is a true textbook that defines concepts starting from first principles. I'll cover the essential information in class, but it 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 primary 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 (instead of email) to ask questions directed towards me or the class.

- **Link:** https://piazza.com/class/...

Software Used

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

Systems Trades Model (STM): STM is an Excel-based "template" developed at the NASA Jet Propulsion Laboratory that helps the user to decompose a spacecraft design into a module-based, hierarchical structure that is mapped into distinct spreadsheets. While STM is *simply* a template, it helps the user(s) to methodically separate a design into individual hardware components, power & cost estimates, parameters, dependencies, and design notes. Note that while STM is a specialized tool for JPL conceptual studies, it is a good example of how Excel is used to build sophisticated systems engineering tools that are common throughout the industry.

Virtual Desktop Infrastructure (VDI): Viterbi MyDesktop is the current label 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
- **Enhanced VDI:** Thermal Desktop, NX
- Access provided to 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/

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.

Matlab: A general-purpose numeric computation environment, with some symbolic capability. An interpreted C-like language, extended with vector and matrix syntax, is coupled with mathematics and graphics libraries. The student who is comfortable with Matlab will be able to do a numerical solution of any problem he or she is faced with, as well as provide graphical representation of the solutions.

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.

Approximate Schedule

The dates 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. Additionally, while your expectation should be that we will have an assignment each week, it is possible that I may remove or combine some assignments, such that the total number of assignments will ultimately be 6-11 (and thus each assignment may be worth as much as 7% of your grade).

• 8/27	Introduction	Survey Due
• 9/3	Propulsion	Reading Quiz, HW Due
• 9/10	Attitude Control System (ACS)	Reading Quiz, HW Due
• 9/17	Control & Data Handling (C&DH)	Reading Quiz, HW Due
• 9/24	Electrical Power System (EPS)	Reading Quiz, HW Due
• 10/1	Complete EPS & Review for Midterm Exam	Reading Quiz, HW Due
• 10/8	Midterm Exam	
• 10/15	Fall Recess (assuming no classes?)	
• 10/22	Telecommunications (Telecom)	Reading Quiz, HW Due
• 10/29	Mechanical (Mech)	Reading Quiz, HW Due
• 11/5	Thermal Control Systems (TCS)	Reading Quiz, HW Due
• 11/12	Payload System (PL)	Reading Quiz, HW Due
• 11/19	Complete PL and/or Topic of Interest	Reading Quiz, HW Due
• 11/26	Thanksgiving	
• 12/3	Guest Speaker, Review for final exam	HW Due
• 12/10, 11am-1pm	Final Exam	

Additionally, at the end of each course lecture, I will provide a more detailed schedule that will cover the following 3-4 weeks, including reading and homework assignments.

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.

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.

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