Department of Astronautical Engineering
aste-classes.usc.edu

ASTE 331b, Spring 2024
Spacecraft Systems Engineering

3 units
Lectures: Fridays 1:00 – 3:50 PM, In-Class (THH 116) and Online
Zoom Link: https://usc.zoom.us/j/... (Meeting ID TBD)
All lectures are recorded and charts will be available prior to start of class.

Instructors

Instructor: 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:		
James Austin	jtaustin@usc.edu	ACS, Power, Telecom, General Q&A
Gage Bachmann	gbachman@usc.edu	Propulsion, ACS, Mechanical, General Q&A
Jennah Saqib	saqib@usc.edu	ACS, Mechanical, Unix/Python, General Q&A
Angela Sayadian	sayadian@usc.edu	Prop, Thermal, Mech, Unix/Python, C&DH, General Q&A

Consultants & Guests:	
Danielle Marsh, Senior Systems Engineer, JPL	Flight System & Payload Design
Steve Balistreri, Senior Systems Engineer, Boeing	EECLS (Human Systems)
Morgan Johansen, Former Senior Engineer	Avionics, I&T, and Flight Systems

Congratulations for completing ASTE 331a and welcome to 331b! Previously, we covered a subset of the spacecraft subsystems (propulsion, GN&C, telecom, C&DH, power, thermal, and mechanical), along with their general interrelationships. This hopefully has given you a basic level of understanding for how a spacecraft functions from which we can now pursue additional breadth and depth. For breadth, we'll be looking at the system-level design that includes the project lifecycle; systems engineering; integration & testing; mission failures and fault protection; and mass, power, data, and cost analyses. For depth, you will dive into your designated subsystem where you will be responsible for the design of your team's concept. As before, these assignments will not be easy, but we will work together to ensure that they are achievable and help provide an understanding of complex engineering design that is critical in the aerospace industry and applicable across many other fields.

As your returning 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 seeing all of you again this semester 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 is the second semester of a two-semester series. While 331a covered the space environment and spacecraft subsystems, this semester (331b) encompasses the integrated spacecraft design, additional subsystem breadth and depth, and a spacecraft design project. For each of these areas, we will discuss the key principles and their application via real-world case studies and design problems. You will continue to learn industry best practices and expand your knowledge of the most common applications, such as Excel, Matlab, and/or Python. This knowledge will complete your foundation of integrated space systems that will provide significant context for the further exploration of astronautics or other industries where complex systems are designed.

Prerequisite: ASTE 331a – Spacecraft Systems Engineering (1st semester)
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 and payload/subsystem interdependencies
- The relationship between mission, system, and subsystem performance requirements
- How to design payloads and subsystems to meet performance requirements
- The steps in performing a complete spacecraft system design
- Balancing design tradeoffs at the subsystem- and system-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 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. For each assignment, you'll complete it either (a) individually, (b) as part of your subsystem group, or (c) as part of your project design team. Note that this "matrix organization" structure is often used at larger organizations to help ensure common standards across technical disciplines and team collaboration across projects. 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.

331b Matrix Organization

	Team 1	Team 2	Team n	
Subsystem 1				Subsystem Group
Subsystem 2				
Subsystem 3				
Subsystem 4				
Subsystem 5				
Subsystem 6				
Subsystem n				
	Design Project Team			

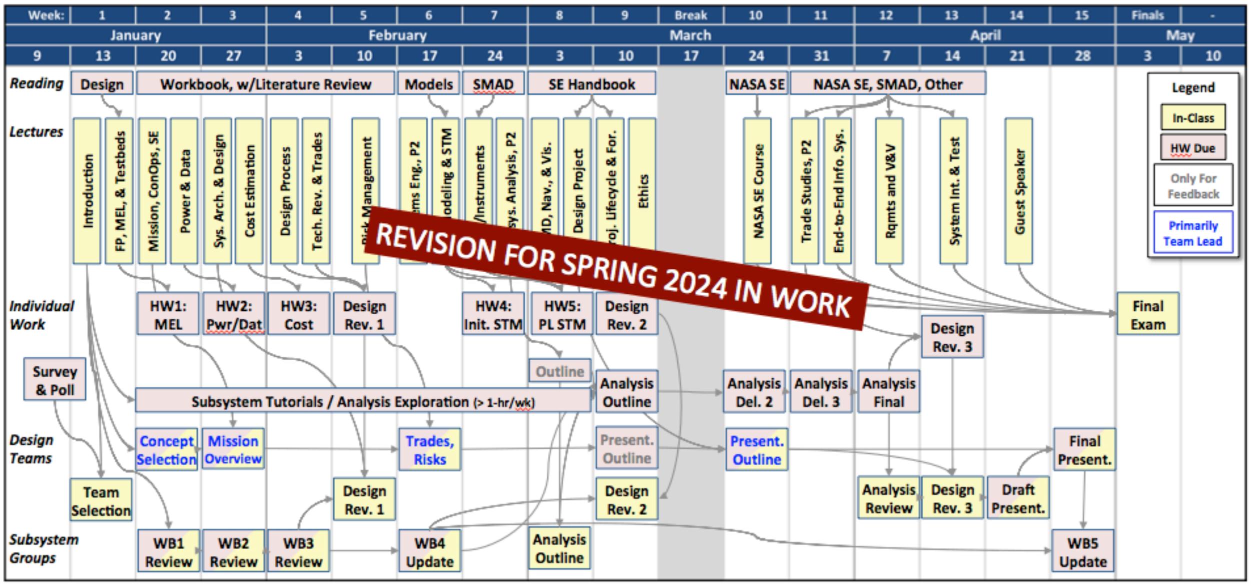
Type		Description	Grading %	Approximate Criteria	Approach
Participation	Lectures	Weekly class lectures, including attendance and participation	10%	• ≥ 90% attendance • ≥ 1 question, answer, or comment per lecture (full class) • ≥ 50% of classes in-person or w/vid-enabled	End-of-month self-assessments that are reviewed, audited, & graded. Note that participation can be traded across categories (e.g., a weekly study group can offset not posting to Piazza).
	Piazza	Posting questions, answers, or comments to online threads		• ≥ 1 post every 2 weeks in Piazza • ≥ 90% of other posts read	
	Small Groups	Participating in study groups or instructor/TA office hours		• ≥ 1 meeting every 2 weeks	
	Feedback	Review all feedback provided by the professor/TAs		• 100% of feedback read, understood, and applied where relevant	
	1-min Eval	Anonymous submission of weekly 1-min evaluation w/course feedback		• ≥ 90% weekly submission rate	Blackboard-generated status

Individual Work	Reading	Weekly reading assignments from SMAD or other references	20%	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
				  ○ 331ab best practices followed?
				  ○ Is the assignment well organized and easy to review?
					Part of HW or possible quiz

	Problem Sets	Excel-based assignments similar to 331a that focus on systems eng.			Instructor/TA grade individually.
	Final Exam	Evaluates your basic understanding of s/c design & systems engineering	5%		
	Subsystem Analysis	In-depth subsystem analysis due incrementally over the semester	20%		
	Subsystem Feedback	Documented feedback on the designs of your subsystem group members.	5%		
Subsystem Groups	Subsystem Workbooks	The continued development of an Excel workbook (from 2021) that will serve as your subsystem design guide	10%		Instructor/TA grade group submissions (group members receive the same grade).
	Design Reviews	Similar to the 331a design problems to support your projects	15%		
Design Project Teams	Team Assignments	Will help structure your designs over the semester (led/submitted by lead)	15%		
	Final Presentation	Presentation of a completed spacecraft design project			

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 this schedule will be discussed in our first class and then I will update it each week as necessary.



Prior 331a Topics: Space Systems, Mission Requirements, Propulsion, ACS/GN&C, Telecom, C&DH, Power, Mechanical, Thermal, & Space Environment.

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 by either Monday or Thursday end-of-day unless otherwise specified. The majority of assignments are required for in-class discussion and thus extensions are generally not allowed. Regardless, all delays should be communicated with me in a timely manner and, in writing, with an estimated completion date. If your requests are feasible (that is, not required by your group/team members) 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. The TAs and 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 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 (e.g., 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 (e.g., 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 (e.g., set of algorithms), please annotate it to show that you understand and agree with the logic (in other words, please don't blindly assume it is correct). 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:** NASA Systems Engineering Handbook Revision 2, Last Updated 9/18/2017, Editor: Garrett Shea. Located at: https://www.nasa.gov/connect/ebooks/nasa-systems-engineering-handbook
3. **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. The NASA SE Handbook (available electronically) is also a great resource that you may use throughout your career as a helpful reference. Finally, 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.

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, STM, 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.

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. It initially functions as a template that helps the user methodically separate a design into individual hardware components, power & cost estimates, parameters, dependencies, and design notes that can be developed collaboratively. While it is a specialized tool for JPL conceptual studies, it is also 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 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. 331b 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.

Systems Toolkit, STK (ANSYS): 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 (ANSYS): 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

In my time as both a student, instructor, and engineer, I am both directly and indirectly knowledgeable of how valuable support systems are and I encourage each of you to reach out when necessary or simply if you have questions. As I know this course is challenging, I will also endeavor to work closely with you and let you know if I have any concerns. Occasionally, my support may include reaching out to student counseling services based on multiple missed assignments, lack of attendance, overall class standing, and/or our general communication. Overall, the priority is your health and well being, and I'll endeavor to help however I can.

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