Department of Astronautical Engineering
aste-classes.usc.edu

ASTE 331b, Spring 2021
Spacecraft Systems Engineering

3 units
Lectures: Fridays 1:00 – 3:50 PM, Online
Zoom Link: https://usc.zoom.us/j/... (Meeting ID 946 1700 8080)
All lectures are recorded and charts will be available prior to the start of class.

NOTE: A recorded lecture may occasionally be created and assigned instead of using the full class time.

Instructors

Jim Chase, chasejam@usc.edu

Office Hours: By appointment.
Preferred times are weekdays (M-Th) early (6-8am), late (4-6pm) or weekends (9am-5pm).
Zoom Link: https://usc.zoom.us/j/5539298026 (Meeting ID 553 929 8026)

TA: Nikita Persikov, persikov@usc.edu
His primary role will be developing a subset of the subsystem analyses (e.g., GN&C).

Office Hours: Piazza is recommended for questions to Nikita. Alternatively, office hours are by appointment.
https://usc.zoom.us/j/97995195809

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 be responsible diving into one of the subsystems 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 you with 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 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 (virtually) 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, which will generally be loosely similar to 331a.

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 331b is the second semester of a two-semester course. The first semester covered the space environment and spacecraft subsystems. The second semester will be about space systems engineering and the design process, along with a spacecraft design project done in teams.

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
- 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 online nature of this year's course, the emphasis of virtual participation has been increased to promote overall engagement with the class via virtual lectures, Piazza, study groups, and office hours. As part of this course, significant time will be spent on a design project, where teams will create a conceptual design. 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.

<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="4">Participation</td><td>Lectures</td><td>Weekly class lectures, including attendance and audio/video participation</td><td rowspan="4">10%</td><td>• ≥ 90% attendance
• ≥ 1 question, answer, or comment per lecture (full class)
• ≥ 50% of classes 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 (e.g., 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 posts/week in Piazza
• ≥ 90% of other posts read</td></tr>
<tr><td>Small Groups</td><td>Participating in virtual study groups or instructor/TA office hours (outside of classes)</td><td>• ≥ 1 meeting every 2 weeks</td></tr>
<tr><td>1-min Eval</td><td>Submission of weekly 1-min evaluation with feedback on the course</td><td>• ≥ 90% weekly submission rate</td><td>Blackboard generates an individualized submission rate, which will be used.</td></tr>
<tr><td rowspan="3">Homework & Midterm</td><td>Individual Assignments</td><td>These range from block diagrams to mass/power/cost analyses.</td><td>25%</td><td rowspan="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?</td><td>Individually graded throughout the semester.</td></tr>
<tr><td>Midterm</td><td>60-min test to evaluate basic understanding of spacecraft design.</td><td>5%</td></tr>
<tr><td>Subsystem Workbook</td><td>An Excel workbook that is developed over the course of the semester and includes a literature review, key parameters, hardware catalog, and model library for your subsystem.</td><td>10%</td><td>Weekly auditing w/final workbook graded. Both group members receive the same grade.</td></tr>
<tr><td rowspan="3">Design Project</td><td>Subsystem Analyses</td><td>These are a set of specified analyses specific to each subsystem.</td><td>10%</td><td>Individually graded.</td></tr>
<tr><td>Team Assignments</td><td>Generally biweekly assignments that will help structure your designs throughout the semester.</td><td>10%</td><td rowspan="2">Submitted and graded as a team.</td></tr>
<tr><td>Final STM & Presentation</td><td>Final Systems Trades Model (STM) and presentation to the class.</td><td>30%</td><td>• See the above
• Overall presentation (via Zoom)</td></tr>
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Assignment Format & Timeliness

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 may try to provide a course handout, "Writing, Presentation, and Analysis Best Practices," that should generally be followed when submitting all assignments. *(Creating this handout is a mid-semester goal and depends on available time.)*

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.

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

Required Readings and Supplementary Materials

The textbooks referenced this semester are:

1. Vincent L. Pisacane, Fundamentals of Space Systems, 2nd ed. Oxford, 2005. ISBN 978-0195162059.
2. Space Mission Engineering: The New SMAD, James R. Wertz, David F. Everett and Jeffery J. Puschell, eds. Microcosm, 2011. ISBN 978-1881883159.
3. 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

Pisacane is a true textbook and explains concepts starting from first principles. SMAD is more of a reference and its explanations are quite terse, but it is more up to date with more information on actual missions. The NASA SE Handbook as a great resource that provides a comprehensive review of systems engineering practices.

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, STM Materials, COVID-19 Information
- **Link:** https://blackboard.usc.edu/...

Piazza: This is a supplemental online site that is used as a forum for online discussions. Please use this site (rather than email) for questions to me/Nikita or the class at large.

- **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. 331b *should* (TBC) have access to both general and enhanced VDI.

- **General VDI:** STK, Matlab
- **Enhanced VDI:** Thermal Desktop, NX
- Access provided through 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/

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 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 there will be no reading quiz on the first day, and the corresponding reading is expected to lag behind slightly.

Week	Date	Class Topics	Assignments Due Prior to Class (unless otherwise specified)		
			Individual	Submitted as a Group	Submitted as a Team
1	1/15	• Introduction & Syllabus Overview • Space Systems and the Product Development Process • Early Formulation and the Design Process	• Response to team survey		
2	1/22	• Design Project Overview • STM Overview (offline)	• Read assigned sections on SE, Spacecraft Design, and STM • HW-1: GRACE Objectives, Concept of Operations, and 2 Block Diagrams		• Review team assignment & list of possible missions
3	1/29	• Mission Design & Nav. (ΔV, Trajectories, C3, & LVs) • Testbeds & Master Equipment Lists (MELs) → HW-2 • Baseline Designs in STM		• Subsystem Workbook (WB)	
4	2/5	• Payloads & Instruments	• Jan. participation self-assessment	• WB	• Draft Objectives • Draft Concept of Operations • Draft Block Diagram
5	2/12	• Power Analysis → HW-3	• HW-2: Testbeds & MEL	• WB	
6	2/19	• Subsystem Analysis Q&A (topics per request)		• WB	• Baseline Design in STM
7	2/26	• EEIS and Data Management → HW-4	• HW-3: Power Analysis	• Baseline Design Feedback	
8	3/5	• Trade Studies • Project Design Process (ECRs, PFRs, etc.)	• Feb. participation self-assessment	• WB	• Initial Subsystem Analyses
9	3/12	• Cost Estimation → HW-5	• HW-4: Data Management	• WB	
10	3/19	• Subsystem Analysis Q&A (topics per request)		• WB	• Subsystem-Level Trades
11	3/26	• Systems Engineering • Flights Software and Fault Protection → HW-6	• HW-5: Cost Estimation	• WB	
12	4/2	• Review for Midterm	• Mar. participation self-assessment	• WB	• System-level Trades
13	4/9	• System Integration & Test	• Midterm Exam • HW-6: Mission Failure Paper	• WB	
14	4/16	• Mission Systems (GDS & MOS)		• WB	• Final Subsystem Analyses
15	4/23	• Model-Based Systems Engineering	• Apr. participation self-assessment	• WB	• STM & Remaining Final Products
16	4/30	• No class (USC Wellness Day)			
	5/5	• Final Presentation		• Proposed Design Feedback	• Submit Final Presentation Charts

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

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