**Department of Astronautical Engineering**
aste-classes.usc.edu

## ASTE 331a, Fall 2020
## Spacecraft Systems Engineering

3 units
Lectures: Fridays 12:30 – 3:20 PM, Online
Zoom Link: https://usc.zoom.us/j/... (Meeting ID 930 3316 3353)
All lectures are recorded and charts will be available prior to the start of class.
Slack Channel: fall20-aste-331a-28489

*NOTE: At our first class, we'll discuss the option of splitting the class into two sessions with one earlier in the week.*

## Instructor

Jim Chase, 818-203-8769 (cell), chasejam@usc.edu

**Office Hours:** By appointment.
Preferred times are weekdays early (6-8am), late (3-5pm) or weekends (9am-5pm).
**Zoom Link:** https://usc.zoom.us/j/5539298026 (Meeting ID 553 929 8026)

**Teaching Assistant:** Nikita Persikov, persikov@usc.edu

**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 virtually 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 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. Also, to encourage reading and small group discussion, there are weekly quizzes that are discussed and submitted via small groups (ie, Zoom breakout rooms). 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 also 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 | 10% | • ≥ 90% attendance<br>• ≥ 1 question, answer, or comment per lecture (full class)<br>• ≥ 50% of classes with video-enabled | End-of-month self-assessments that are reviewed, audited, & graded by the instructor/TA.<br><br>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 | | • ≥ 2 posts/week in Piazza | |
| | Small Groups | Participating in 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 | 5% | • ≥ 90% weekly submission rate | Class receives the same grade based on % submitted each week. |
| Homework | Reading | Weekly reading assignments and quizzes (via small groups) in advance of the corresponding lectures. | 5% | • Consistent/accurate responses relative to peers | Instructor/TA grades each group submission. No quiz the first week. |
| | Problem Sets | Weekly problem sets that will typically be completed in Excel or Matlab. | 35% | • Technical accuracy<br>• Communication & formatting | Instructor/TA grade individually. |
| Exams | Mid-Term | 80-min exam to evaluate understanding of weeks 1-7 | 15% | • Technical accuracy | |
| | Final Exam | 120-min exam to evaluate overall course understanding | 30% | • Technical accuracy | |

## 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 will provide a course handout, "Writing, Presentation, and Analysis Best Practices," that should generally be followed when submitting all assignments.

The expectation is that you will complete assignments prior to each Friday class. 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 (eg, 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 (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 are two required textbooks:

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.

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.

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 students 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 the instructor or the class at large.

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

**Slack:** This is an additional site primarily for instant messaging. Good forum for quick messages or questions that can be easily answered. More complex or longer questions should be addressed in Piazza.

- **Channel:** fall20-aste-331a-28489

## 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 from Aug. 17th 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 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 | TENTATIVE Topics | Reading (prior to class) | | Homework | |
|---|---|---|---|---|---|---|
| | | | FSS | SMAD | Assigned | Due |
| 1 | 8/21 | • Spacecraft Systems Engineering Overview<br>• Intro to the System Trades Model (STM) | 2.1, 2.3, 2.4 | 1.1, 1.2-4, 1.5, 2.1-3, 3.1, 3.2-3, 3.4 | HW-1 | |
| 2 | 8/28 | • Mission requirements flow-down<br>• Propulsion-1 | **4.1-2**, 4.3-4.8 | **14.1-4, 3.5**, 4.1-4.4, **6.1-2** | HW-2 | HW-1a |
| 3 | 9/4 | • Propulsion-2 | **4.9-11**, **4.15** | **18.1-5** | | HW-1b<br>HW-2a |
| 4 | 9/11 | • GN&C-1 | **5.1-4**, 5.5-8 | | HW-3 | HW-2b |
| 5 | 9/18 | • GN&C-2 | | **19.1** | | HW-3a |
| 6 | 9/25 | • Telecom-1 | **9.1-5**, 9.6 | | HW-4 | HW-3b |
| 7 | 10/2 | • Telecom-2 | | **16.1-3**, 21.1 | | HW-4a |
| 8 | 10/9 | • C&DH-1 and the space environment<br>• Mid-term Exam | **11.1-4**, 11.5, **2.1, 2.3-4** | **7.1,** 7.2-7.5 | HW-5 | HW-4b |
| 9 | 10/16 | • C&DH-2 | | 20.1-2 | | HW-5a |
| 10 | 10/23 | • Power-1 | **6.1-2**, 6.3, **6.4-9** | | HW-6 | HW-5b |
| 11 | 10/30 | • Power-2 | | **21.2** | | HW-6a |
| 12 | 11/6 | • Mechanical | **8.1-7**, 8.8-17 | **22.1** | HW-7 | HW-6b |
| 13 | 11/13 | • Thermal<br>• Review | **7** | **22.2** | | HW-7 |
| 14 | 11/20 | • Final Exam, 11:00 AM – 1:00 PM | **Note:** Reading quizzes will pull from the **bolded** sections. | | | |

**Second-Semester Topics:** Systems Engineering, Mission Design and Navigation, Payload/Instruments, Flight Software & Fault Protection, C&T/EEIS, Mechanical/Thermal Analyses, V&V/SIT/ATLO, and Cost Estimation.

## 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