Space Science and Engineering: Theory and Applications (ESE/EPS 160)

Winter 2023, 9:00 – 10:15 am, Tuesday and Thursday

Instructor: Prof. Robin Wordsworth (rwordsworth@seas.harvard.edu)

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Location: MD 119 (Grace Hopper Conference Room, Maxwell Dworkin Building)

Note: Syllabus updated 9/4/23

Motivation

Remote sensing by spacecraft is vital to modern Earth science and plays a key role in evaluating the impact of human activity on natural environments. Robotic orbital and lander missions to Venus, Mars, Jupiter, Saturn and other planets have also revolutionized our understanding of the other planets and moons in the solar system. The aim of this course is to introduce the scientific motivation for space missions and the key engineering challenges faced by mission planners. Our goal is to achieve a broad, yet quantitative overview of the key issues involved in both Earth observation and planetary mission design.

Learning Outcomes

You will be able to explain the key scientific problems that can be addressed by spacecraft missions and understand the complementary roles of remote sensing and in situ observations. You will learn the major requirements of a successful Earth orbit or planetary mission, including the core physical concepts necessary to design a launch system, execute orbital transfers, and deliver payloads to planetary surfaces. You will gain the knowledge required to balance power, mass, thermal, data transfer and observational requirements in real missions. You will gain experience of the challenges inherent to spacecraft design through the conceptual design of your own mission in the final project.

Requirements and Resources

Math 21a/b (or Applied Math 21a/b) and Physics 12a/b are prerequisites. If you haven't taken these courses, permission from the instructor is required. Some of the in-class activities will involve writing or editing code written in Python, but previous experience is not assumed. A coding refresher tutorial will be run in the first week of the semester.

The course website will be updated before each class with lectures slides and videos. This year, the course will be mostly operating in a flipped classroom format. More information about the class format will be given on the first day.

There is no required textbook for this course. When appropriate, I will put additional reading material on the course website or provide links to resources on the internet. The following textbooks may be useful for background knowledge:

Fundamentals of Space Systems, 2005, V. L. Pisacane ed., Oxford University Press, New York, USA, ISBN 978-0195162059.

Orbital Mechanics, 2013, Prussing & Conway, Oxford University Press, New York, USA. ISBN 978-0199837700.

Principles of Planetary Climate, 2010, R. T. Pierrehumbert, Cambridge University Press, New York, USA, ISBN 978-052186556-2.

Course Schedule

Module	Title
1	Introduction and Motivation
2	Planetary Atmospheres and Surfaces
3	Launch Systems and Propulsion Physics
4	Celestial Mechanics and Astrodynamics
5	Remote Sensing and Telecommunications
6	Power and Thermal Subsystems
7	Structural Design and Attitude Control
8	Systems Analysis & Final Project Presentations

Note that this schedule may be subject to change. Any significant alterations will be listed on Canvas.

Assessment

- **Participation** (30 % of final grade). Starting this year, this course will not have take-home problem sets. These have been replaced by in-class activities, some of which will involve working with hardware. You will be graded on your participation in these exercises.
- **Pre-class quizzes** (15 % of final grade). Each week, short multiple choice quizzes will be posted on Canvas that test your knowledge of the online material in preparation for the in-class activities. The quizzes are not as challenging as traditional problem sets, but you must complete them on your own.
- **Mid-term exam** (25 % of final grade). The mid-term exam will take place in early November and will test knowledge of the first four modules. It will be an in-person exam, and internet access will not be permitted. Calculators will be provided, and you are permitted to bring in one page of hand-written notes (double-sided).
- **Final project** (30 % of final grade). The final project will involve conceptual design of a space mission of your choosing, within fixed constraints of mass and volume. Working in teams of 2-3, you will present mission proposals describing your spacecraft design and its scientific motivation and write up final reports. You will be assessed on the novelty and feasibility of your mission and the quality of your technical analysis. The final project presentations will take place during the last two lessons of class, and reports will be due during exam period at the end of the semester.

General Course Policies

We aim to maintain a respectful and inclusive atmosphere in the class that values diverse perspectives. Any suggestions on how we can improve on this are always welcome. All students are strongly encouraged to participate in class discussions. We ask students to be present during in-class activities and avoid usage of social media or similar distractions. In-person class attendance is a key component of the course, and if you are unable to make a lesson for a specific reason (e.g. medical appointments, religious holidays), please let us know in advance.

Finally, a reminder: if you are an engineering concentrator, you should enroll in ESE 160 rather than EPS 160. This is for administrative reasons only and will make no difference once you are enrolled in the course.

GAI Policies

In our experience, generative artificial intelligence (GAI) tools such as ChatGPT can be powerful learning facilitators, but they must be used with caution. We will have plenty of in-class discussion about this important topic. Engagement with GAIs is permitted during in-class group activities, but should only be done if you feel it is helpful for the learning experience of yourself and your group members. Discussion with GAIs is also permitted for the final projects, although a clear statement of contribution is mandatory in the final report writeup. Final report grading will take into account the extent to which ideas and text presented in the final report are your own.

Discussion with GAIs is *not* permitted during the mid-term exam or during completion of the pre-class quizzes. Violations of these policies will be considered academic misconduct. We draw your attention to the fact that different classes at Harvard could implement different AI policies, and it is the student's responsibility to conform to expectations for each course.