# Space Science and Engineering: Theory and Applications (ES 160)

Winter 2016, Daly Room, 10 – 11:30 am, Tuesday and Thursday

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Course Website: https://canvas.harvard.edu/courses/16543

## 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, Mercury, Titan and other bodies 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 observation 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 problem sets and the final project in this course will involve writing code in high-level languages such as Matlab or Python. In case your coding skills are rusty, TF Taylor Jones will run a Matlab refresher tutorial in the first few weeks of term (timing to be arranged).

Office hours are by arrangement. You can also contact us by email with any questions (email addresses given at the top of the page), or simply come to chat after the class. The course website will be regularly updated with notes from the lectures, additional course material, problem sets and grades. 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:

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

*Planetary Surface Processes*, 2011, H. J. Melosh, Cambridge University Press, New York, USA, ISBN 978-052151418-7.

*Spacecraft Systems Engineering*, 2011, P. Fortescue, G. Swinerd, J. Stark eds., Wiley, Chichester, United Kingdom, ISBN 978-0470750124.

*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.

*Rocket Propulsion Elements*, 2010, G. P. Sutton & O. Biblarz, Wiley, Hoboken, USA, ISBN 978-0470080245.

*Exploration of the Solar System by Infrared Remote Sensing*, 2003, R. A. Hanel et al., Cambridge University Press, Cambridge, UK, ISBN 0 521 81897 4.

## Course Schedule

| Lesson | Title |
|---|---|
| 1 | Introduction and course overview |
| 2 | Scientific Motivation |
| 3 | Planetary Atmospheres I: The lower atmosphere |
| 4 | Planetary Atmospheres II: Above the mesopause |
| 5 | Planetary Surfaces |
| 6 | Rocket Dynamics |
| 7 | Propulsion systems |
| 8 | Celestial Mechanics I |
| 9 | Celestial Mechanics II |
| 10 | Orbital Transfers I |
| 11 | Orbital Transfers II |
| 12 | Planetary Lander Descent Techniques |
| 13 | Remote Sensing I |
| 14 | Remote Sensing II |
| 15 | Telecommunications I |
| 16 | Telecommunications II |
| 17 | Spacecraft Thermal Control I |
| 18 | Spacecraft Thermal Control II |
| 19 | Power Management I |
| 20 | Power Management II |

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| 21 | Attitude Control |
| 22 | Spacecraft Structures |
| 23 | Systems Analysis & Final Project Discussion |
| 24 | Guest Lecture / Revision |
| 25 | Guest Lecture / Revision |

Note that this schedule may be subject to change. Any significant alterations will be emailed and listed on the course website.

## Assessment

- **Attendance** (5 % of final grade).
- **Problem sets** (35 % of final grade, 8 in total): Problem sets are handed out every 3 lessons and are due 3 lessons after the hand-out date. You are welcome to discuss the problem sets together but solutions must be your own work. You should always show your working, including any code you write in questions that involve numerics.
- **Final exam** (30 % of final grade). Exam is 90 minutes and will take place in class. You will be permitted 1 US letter / A4 page of handwritten notes and a calculator. Internet access on a computer or mobile device will not be permitted.
- **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 write a mission proposal describing your spacecraft design. Justifying the scientific motivation for the spacecraft will be a key part of the project. You will be assessed on the feasibility of your design and the rigour of your technical analysis. More details will be given on the project in the second half of the course. The final project will be due during exam period.

## Course Policies

Regular attendance at lectures is required and all students are encouraged to participate in lecture activities and discussions. Lectures will be carried out in "Airplane Mode" – any device with wireless capability must have the wireless feature turned off throughout the lecture. Late problem sets will be accepted up to 48 hours after the due date, but their final grade will be capped at 70% of the total mark. In all submitted work, you must always cite the source of any information you use.