ASEN 5335, Aerospace Environment: Syllabus

Location and Time: AERO 111, MWF 09:35 – 10:25 am
And on zoom:

Instructor: Dr. Yang Wang (yang.wang-2@colorado.edu)
Office: AERO 415
Office hours: Friday, 11am-12pm in my office and 12pm-1pm on zoom
(at the same zoom link above)

Teaching Assistant: Nick Dietrich (nicholas.dietrich@colorado.edu)
Office hours:
Thursday, 3-5 pm in-person Aero 414 and 4-5 pm on zoom.

1 Overview

Aerospace Environment is a core course in the Remote Sensing, Earth & Space Sciences (RSESS) focus area, meant to introduce you to the near-Earth space environment and its effects on spacecraft, communications systems, astronauts, and more. Aerospace engineers working on space technology or applications need a broad understanding of the environment in order to design their spacecraft appropriately. But more generally, anyone with a passion for space will be fascinated to learn about the different regions of the space environment, how they couple together and affect each other, and how they affect our daily lives.

We define the "near-Earth" space environment as the region of space surrounding the Earth which is affected by the sun and where most of our satellites operate. As such, this course focuses on the space environment surrounding the Earth – don't expect to learn about the solar system, galaxies, interplanetary space, and so on. However, we will take a look at the environments around other planets for comparison with Earth, for example the "near-Jupiter" space environment.

The near-Earth space environment extends from the surface of the Earth up to the bow shock, which is the outer boundary of the magnetosphere. Within this environment there are different overlapping regions: the atmosphere, made up of neutral molecules and atoms; the ionosphere, where the gas of the atmosphere becomes ionized; the plasmasphere, where the gas is completely ionized and trapped in Earth's magnetic field; and the radiation belts, which contain high-energy electrons and protons. These regions are affected by Earth's magnetic field, and the region where this field is dominant is called the magnetosphere. Within the magnetosphere there are different populations of particles, different electric currents, and all sorts of complex plasma and electromagnetic waves. In addition, the environment also contains dust and meteoroids that live in our solar system, as well as the spacecraft and orbital debris that we are directly responsible for.

In this course we will learn about each of these regions, why they exist, and the positive and negative effects they have on spacecraft, astronauts, and different aspects of society. There are electrical and radiation effects on spacecraft and astronauts; effects on the communications signals from GPS and other spacecraft; effects on the ground due to magnetic field perturbations; impacts on spacecraft by dust and meteoroids; and much more. The course is organized into **Modules** covering each of the regions of the space environment, with each module encompassing roughly two weeks. In each module, there will be reading from the assigned textbooks and from course notes; lecture slides and videos; and a set of homework problems.

To give some contextual reference, we will discuss one or two spacecraft missions in each module. We'll talk about the missions in lecture, but you'll have to do some background reading to learn what these missions are up to. These are meant to highlight the state-of-the-art in our knowledge of the space

environment, and to give you an idea of how the scientific community learns more about the environment.

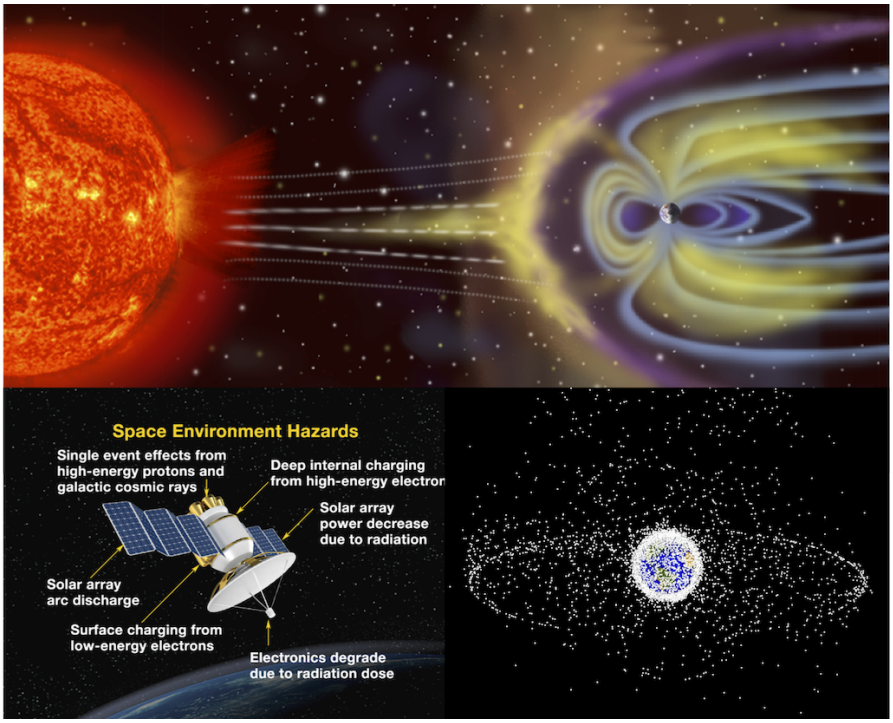

Figure 1: Top: Depiction of the space environment and its response to solar inputs. Bottom left: Hazards to spacecraft due to the space environment. Bottom right: the orbital debris environment around Earth – individual objects not to scale!

2 Prerequisites & Eligibility

This course is open to all CU Boulder ASEN graduate students and BAM students. Undergraduate students (non-BAM) can request enrollment on a case-by-case basis. There will be some math and physics in this course, so these prerequisites are strongly recommended:

- **Physics II (Electricity and Magnetism)**. The space environment is full of plasma, fluid waves, and electric and magnetic fields. We will also discuss a number of aspects of electronics.
- **Calculus III (Vector Calculus)**. Electric fields, magnetic fields, and waves in the space environment are all described by vector calculus, and an understanding of this math is critical.

3 Reading Materials

Required reading materials for this course are:

- Dolores Knipp, "Understanding Space Weather and the Physics Behind It", McGraw Hill, 2011: a comprehensive book focused on space weather, targeted at graduate students. Specific sections and pages will be assigned with each module.
- Other reading, websites, papers, documents, and homework assignments distributed on Canvas (see below)

Optional reading material that may be of interest to students include:

- Thomas Tascione, "Introduction to the Space Environment", Krieger Publishing, 2010.
- Alan Tribble, "The Space Environment: Implications for Spacecraft Design", Princeton, 2003.
- Vincent Pisacane, "The Space Environment and Its Effects on Space Systems", AIAA, 2016: a large reference book with emphasis on effects on specific spacecraft systems.

4 Subject Outline

1. Most of space physics is driven by **the Sun and the Solar Wind**. We'll discuss it's structure and dynamics and how it provides the inputs to our environment.
2. The sun's outputs directly impact the Earth's **Magnetosphere**. We'll learn about the origin of the magnetic field, it's structure, and how it responds to solar inputs.
3. Within the magnetosphere are trapped **Radiation Belts**, which are highly damaging to spacecraft. We'll learn about these intense radiation regions, as well as other sources of radiation.
4. The Earth's **Atmosphere** provides our primary source of protection from radiation, but is also an integral part of the space environment.
5. The sun's UV radiation partially ionizes the atmosphere, forming the **Ionosphere**, a complex region with important dynamics and coupling to the atmosphere.
6. **Micrometeorids and Orbital Debris** (MMOD) are an important part of the space environment, with critical effects on spacecraft.
7. Finally, we'll discuss the space environments of **Mars and Jupiter**; these interesting environments highlight what is unique about each as well as what they have in common.

5 Logistics

1. **Office Hours**: I will have office hours in person and on Zoom, to accommodate remote students. If you can't make the scheduled times but wish to meet, please e-mail me to arrange another time. Meetings will be allocated half-hour time periods unless more time is requested.
2. **Assignments**: For each module we will post **one** document. This document includes reading material prepared by us for your benefit; mission assignments with key points for you to look out for; and problems/questions that constitute the homework assignment for that module.
3. **Homework**: Homework due dates are given in the detailed schedule, but dates on the assignment document or Canvas take precedence in case the schedule is updated. **Homework will be self-graded**. You'll turn in your work at the deadline for partial credit, at which point you'll be given the answers and/or solutions. You can then revise your work and re-submit it by a second deadline for the remaining credit.
4. **Collaboration**: I encourage collaboration on homework assignments, discussion about missions, and so forth, but each student must submit her or his own work for each assignment. Do not simply copy each other if you collaborated; collaborate on solutions, but document the work individually. Collaboration on quizzes and exams is **not** permitted.

5. **Communications**: Class communications, including announcements, outgoing assignments, incoming submissions, and discussions, will be conducted through Canvas.

6 Grading

Grading will be based on the following course components:

Element	Fraction
Homework Assignments	20%
Quizzes #1–6	10% each
Final Exam	20%

Homework Assignments: As described above, homework assignments are integrated into the single document for each module. You will get 70% of the credit for completing the assignment and submitting it on time. You will then have access to the homework solutions; you'll get the other 30% for re-submitting the assignment with corrections to your own work noted. The first submission has a hard deadline of 5 pm on the due dates. **It cannot be submitted late**. This is because the solutions will be posted immediately thereafter. The second submission, after the due dates, will accrue a late penalty of 10% per day until it reaches zero.

Exams: There will be six unit quizzes, one for each of the first six modules, as well as one final exam. The quizzes will cover material in the current module, but may require knowledge from earlier modules. The quizzes will be administered through Canvas. You'll have an over 24-hour window to complete them, but only one hour once you start. Each quiz is worth 10% of the final grade. The final exam will be comprehensive, will be scheduled for the regular final exam window, and will be worth 20% of the final grade.

Participation: Attendance and participation in class discussions are required. Lectures are designed to have lots of questions from students and engaging discussion. Please e-mail me if you expect to have excused absences from the lecture. While there is no grade for participation, I will take it into account when I consider "edge cases" in final grades.

7 University Policies

7.1 Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

7.2 Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

7.3 Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

7.4 Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

7.5 Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and the support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

7.6 Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the campus policy regarding religious observances for full details.