ASEN 5335, Aerospace Environment: Syllabus

Location and Time: AERO 114, M/W 3:00 – 4:15 pm

Instructor: Prof. Robert Marshall

Teaching Assistants:
Nicole Futch
Charlie Priebe
Office hours: TBD (will be posted on Canvas)

1 Overview

Aerospace Environment is a core course in the 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.

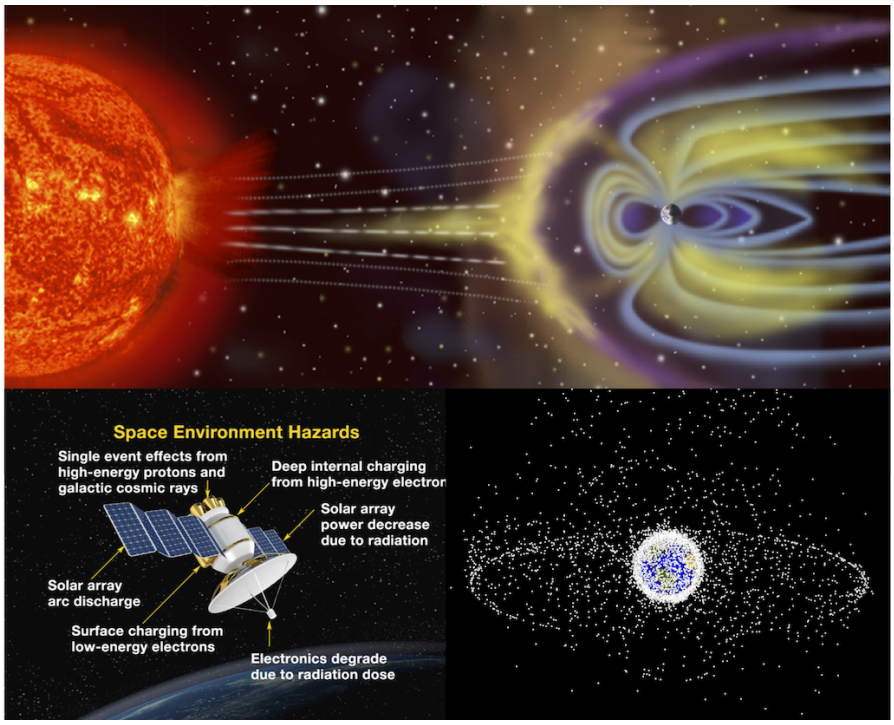

Figure 1: Top: Depiction of the space environment and its response to solar inputs. Bottom left: Hazards to spacecraft due to the space environment. Bottom right: the orbital debris environment around Earth – individual objects not to scale!

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.

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:

- 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. 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:

- Dolores Knipp, "Understanding Space Weather and the Physics Behind It", McGraw Hill, 2011.
- Thomas Tascione, "Introduction to the Space Environment", Krieger Publishing, 2010.
- Alan Tribble, "The Space Environment: Implications for Spacecraft Design", Princeton, 2003.

4 Subject Outline

Table 1 gives an overview of the topics covered in this course.

Module	Topic	Missions	Due
0	Overview & Course Intro		
1	The Sun & the Solar Wind	Parker Solar Probe, Solar Orbiter	HW1
2	The Earth's Atmosphere	CHAMP, DANDE, GDC	HW2
3	The Earth's Ionosphere	ICON, Ampere	HW3
4	The Earth's Magnetosphere	SWARM, MMS	HW4
5	The Radiation Environment	Van Allen Probes, Arase, FIREBIRD	HW5
6	Micrometeoroids and Orbital Debris	LDEF	HW6
7	Comparative Environments: Mars, Jupiter, etc	MAVEN, Juno, Cassini-Huygens	HW7

Table 1: Overview of topics covered in each module, each covering roughly two weeks.

1. Most of space physics is driven by **the Sun and the Solar Wind**. We'll discuss the sun's structure and dynamics and how it provides the inputs to our environment.
2. The Earth's **Atmosphere** provides our primary source of protection from radiation, but is also connects to other regions of the space environment.
3. The sun's UV radiation partially ionizes the atmosphere, forming the **Ionosphere**, a complex region with important dynamics and coupling to the atmosphere and magnetosphere.
4. 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.
5. 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.
6. **Micrometeoroids 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. The two TFs will have their own office hours. We will schedule office hours to spread the times throughout the week, including within and outside regular work hours. If you can't make the scheduled times but wish to meet, please e-mail one of us to arrange another time. Meetings will be allocated 30 minutes unless more time is requested.

2. **Assignments**: For each module we will post **one main document**. This document includes some condensed review material; mission assignments with key points for you to look out for; and problems/questions that constitute the homework assignment for that module. The due dates for these assignments are posted in the outline above and on the document; **dates on the assignment document take precedence** in case the schedule is updated.

3. **Missions**: Each module will have one or two spacecraft missions to discuss. We use these missions to highlight the latest in research in the space environment and to show how we investigate the environment. We will also discuss the technical aspects of how these spacecraft are designed to *survive* the space environment. We will point you to specific websites to learn about each mission, but in general a good place to start is the Earth Observation Portal (eoPortal) Directory, which has detailed (but sometimes out-of-date) descriptions of just about every spacecraft imaginable.

4. **Homework**: Homework deadlines will be given in the detailed schedule. **Homework will be self-graded**. You'll turn in your work at the deadline for partial credit (graded for completeness), 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.

5. **Collaboration**: We encourage collaboration on homework assignments, discussion about missions, and so forth, but each student must submit their 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.

6. **Communications**: To communicate with the instructor, TAs, and other students in the class, we will use a dedicated Slack workspace, "ASEN 5335: Aerospace Environment", available at: Please use Slack instead of email! You can DM the instructor or TA; but if you have content or homework questions, use the appropriate Slack channels to allow other students to see your questions and the answers (or even answer them). We want you to use Slack as a forum for collaboration!

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 (due on Mondays). You will then have access to the homework solutions; you'll get the other 30% for re-submitting the assignment on Friday, *highlighting* corrections to your own work.

The first submission, due on Mondays, has a hard deadline of 5 pm. **It cannot be submitted late**. This is because the solutions will be posted immediately thereafter. If you haven't completed it, submit what you have; that's better than submitting nothing or asking to submit it late. If you have a conflict on the due date: plan ahead and submit it early! You're given lots of time to complete the homework assignment as the module progresses.

The second submission, due on Fridays, will accrue a late penalty of 10% per day until it reaches zero. You can also have one late submission, no questions asked, but this applies only to this second submission.

Quizzes and 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 a 24-hour window for each quiz, but only one hour once you start. Each quiz is worth 10% of the final grade. The final exam, which takes a similar format as the quizzes, will be comprehensive and will be worth 20% of the final grade.

Participation: Attendance and participation in class discussion is strongly encouraged! Lectures are designed to have lots of questions from students and engaging discussion. Please Slack me if you expect to have excused absences from lecture. While there is no explicit grade for participation, it will be taken into account when we consider "edge cases" in final grades.

7 University Policies

7.1 Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure 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, marital status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

7.2 Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

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.

If you have a temporary illness, injury or required medical isolation for which you require adjustment, please notify the instructor as soon as possible so that appropriate accommodations can be made. If you are sick or require isolation please notify the instructor of your absence from in-person activities and continue in a completely remote mode, as you are able, until you are allowed or able to return to campus. Please note that for health privacy reasons you are not required to disclose to the instructor the nature of your illness or condition, however you are welcome to share information you feel necessary to protect the health and safety of others within the course.

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. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), 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 Student Conduct & Conflict Resolution: studentconduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Codefor more information on the academic integrity policy.

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. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email CUreport@colorado.edu. Information about university policies, reporting options, and support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors must inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support for a variety of concerns, visit the Don't Ignore It page.

7.6 Religious Accommodations

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation in a timely manner. In this class, students are expected to notify the instructor at least two weeks in advance of the conflict to request special accommodation. If possible, the due dates for homework will be adjusted, and quizzes or exams rescheduled to an alternate date. Students should be prepared for due dates or quiz / exam dates to fall on an *earlier* date than the scheduled date, if that turns out to be the most practical solution.

See the campus policy regarding religious observances for full details.

7.7 Mental Health and Wellness

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.

7.8 CU Community of Care

CU Boulder is committed to a community of care in which students are supported by faculty and staff throughout their college journey. You don't have to face academic challenges alone – CU and the college

are here to help you learn and succeed in your coursework and campus life. Part of this community of care is your connection to faculty and staff across campus. Our college promotes and hopes you will connect with faculty or staff who may reach out during your educational journey at CU.

7.9 Course Alerts

This course participates in the CU Course Alert process to help connect you with support resources and identify your barriers to success (colorado.edu/engineering-advising/coursealerts). If you receive a course alert for this class, please reach out to schedule a meeting with the instructor to discuss resources and plans to help get you on track.