ASEN 5335, Aerospace Environment: Syllabus

Location and Time: AERO 114, M/W 8:30 – 9:45 am

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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.

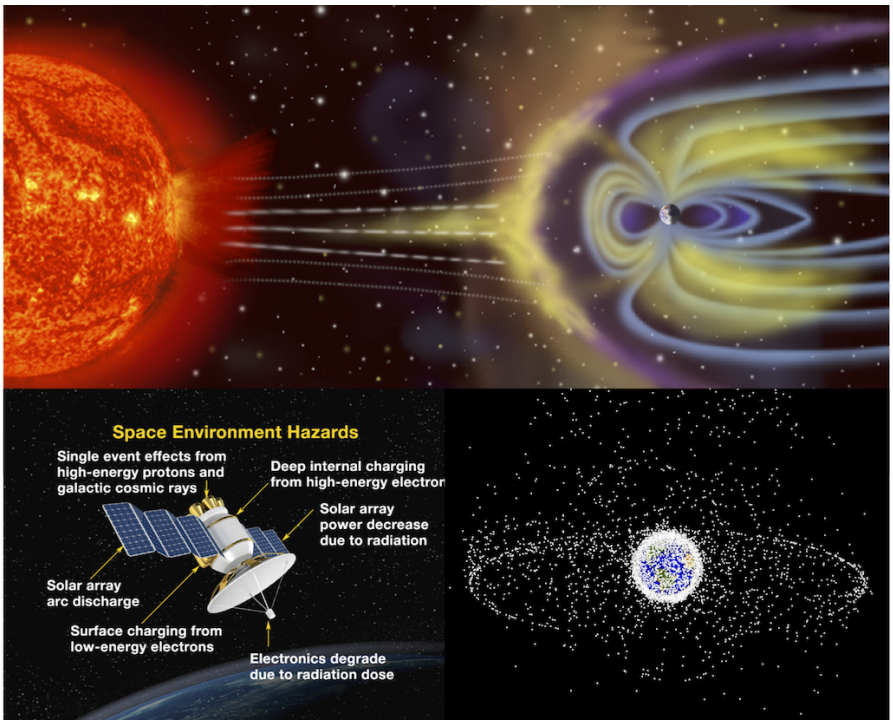

Figure 1: Top: Depiction of the space environment and its response to solar inputs. Bottom left: Hazards to spacecraft due to the space environment. Bottom right: the orbital debris environment around Earth – individual objects not to scale!

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:

- 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

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. If you can't make the scheduled times but wish to meet, please e-mail me to arrange another time. Meetings will be allocated 30 minutes unless more time is requested.

2. **Assignments**: For each module we will post **one 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 asen5335aeros-osm4481.slack.com. 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.

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.

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 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 and will be worth 20% of the final grade.

Participation: Attendance and participation in class discussion is a must! 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, 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 Requirements for Infectious Diseases

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the further guidance of the Public Health Office. For those who have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home.

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

Disability Services determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance.

If you have a temporary medical condition or required medical isolation for which you require accommodation, 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. Also see Temporary Medical Conditions on the Disability Services website.

7.4 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.

7.5 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: honor@colorado.edu, 303-492-5550. 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.

7.6 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 sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on and off campus.

Visit OIEC for or more information about university policies, reporting options, and support resources. If you believe you may have been subjected to misconduct, email OIEC or call 303-492-2127.

Faculty and graduate instructors are required to inform OIEC when they learn of any issues related to these policies regardless of when or where they occurred. This ensures that individuals impacted receive information about their rights, support resources, and resolution options. Visit the Don't Ignore It page to learn more about reporting and support options.

7.7 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. In this class, you must let the instructor know of any such conflicts within the first two weeks of the semester so that they can work with you to make reasonable arrangements.

See the campus policy regarding religious observances for full details.