

ASEN 6080: Statistical Orbit Determination Syllabus, Spring 2023

Lecture: Tuesdays & Thursdays, 16:00 – 17:15 in AERO 114

Instructors

Dr. Yu Takahashi

Office: N/A

Email: yu.takahashi@colorado.edu

Office Hours: See below for details

Course Website

<https://canvas.colorado.edu>

We will be using Canvas, CU Boulder's learning management system. We will be using Canvas for posting all class information (assignments, notes, slides); work will also be turned in and returned through this site. There will also be a discussion board that will be used.

To access Canvas, go to: <https://canvas.colorado.edu>. Log-in using your CU login name and IdentiKey password.

Once you log-in, click on ASEN6080 to go into our course.

Make the most out of Canvas by downloading the Canvas Student App to view your grades, view course materials, submit assignments, take quizzes, and more.

Subscribe to notifications to be reminded of due dates, receive announcements, and grades. Browsing the Canvas Guides or help videos for information on how to use Canvas. If you run into any problems, click the Help Icon within Canvas to report a problem or chat 24x7 with Canvas Support.

For additional assistance, contact the IT Service Center at help@colorado.edu or 303-735-4357.

Course Text

Required:

- Statistical Orbit Determination, Byron D. Tapley, Bob E. Schutz, and George H. Born, 2004.

Not required, but recommended for more technical reading:

- Factorization methods for discrete sequential estimation, Gerald J. Bierman, 1977 (or Dover in 2006)
- Stochastic Processes and Filtering Theory, Andrew H. Jazwinski, 2007.

Not required, but **highly** recommended to be an OD expert:

- Deep Space Communications and Navigation Systems (DESCANSO): <https://descanso.jpl.nasa.gov/>.
 - The book series are available for download for free. These are the legends of JPL documenting the 101 of deep space navigation techniques.
 - In particular, Volume 2 on observables models is of utmost importance: <https://descanso.jpl.nasa.gov/monograph/mono.html>
 - Evolution of Deep Space Navigation is an interesting read: <https://descanso.jpl.nasa.gov/evolution/evolution.html>

And a fun read if you want to learn about the history of navigation:

- The Navigators – A History of NASA’s Deep Space Navigation, Andrew J. Butrica.

Course Description

ASEN 6080 is a course providing an in-depth discussion of advanced orbit determination (OD) techniques. The focus is on the fundamentals of these methods based on non-linear estimation theory and, critically, the ability to implement them in software.

This class will be challenging. The instructor assumes you have a strong background in math (particularly calculus, trig functions, vector, linear algebra, statistics) and physics (particularly general dynamics, orbital mechanics, attitude dynamics). Little to no review will be provided in class on those topics.

Treat this class as if it is your real job. This is more than a class. While the instructor aims to make the class fun and teach everyone the basics of Navigation/Orbit Determination, his real goal is to develop a full-fledged OD analyst in each student. The consequence of not doing that is at best mediocre OD solutions that will compromise the mission success, and at worst a lost spacecraft. We cannot tolerate either.

In return for students' (significant) effort, the instructor intends to teach the materials from his firsthand experience on the real world Orbit Determination. Trust me, the class will be more fun if you put in effort to keep up.

Also, remember that you will be as good as the questions you ask. Don't be afraid to ask questions to dive deeper into the world of OD.

Course Format

The course will consist of two weekly lectures, homework and three projects. The third project may be cancelled at the instructor's discretion. Lecture attendance is highly recommended since many topics are not covered in the course textbook. Think of the projects as bigger homework. The due dates for homework/projects will vary depending on their complexity.

Collaborative study and exploration of the course material is highly encouraged. Think of your peers as a fellow OD analyst on your operations (ops) team. For the online students this may be harder, but you are highly encouraged to participate in the class discussion board on Canvas to share your creativity (more on this below). Please do not isolate yourself. The real OD is a team effort. "If you want to go fast, go alone. If you want to go far, go together."

Course Grading

- Nominal (with the third project):
 - Project 1 15%
 - Project 2 15%
 - Project 3 15%
 - Homework 55%

- *Contingency (only two projects):*
 - *Project 1* 20%
 - *Project 2* 20%
 - *Homework* 60%

Homework

Electronic submission of each homework (in pdf/zip) is due at/by the beginning of lecture on the specified due date. Late assignments will not be accepted unless there are extenuating circumstances (at my judgement).

Homework is where you build the tools for your projects. If you cannot make homework work, then you will not be able to complete your projects.

What the instructor is looking for in the homework is the logical thinking behind your solutions. Having the right answer will not be sufficient. Even if you can't get the right answer, if you can reasonably explain your approach/methods in a coherent way, you will get a good grade. Thus, do not just turn in numbers. Make each submission a mini report/paper with appropriate tables and figures (don't forget captions). The use of LaTeX is highly recommended (this syllabus was made in Word. Not recommended!).

Also, please submit your codes in a **zip file**. The main report and zip file must have **[assignment_lower_case]_[last_name]_[type]** in the file name (e.g., hw1_takahashi_report.pdf, hw1_takahashi_code.zip, project1_takahashi_report.pdf, etc).

Homework grading is on a scale of 0 → “√--” → “√-” → “√” → “√+” scale as follows (percent equivalent in parentheses).

- 0 = assignment not turned in
- “√--” = assignment turned in, but either not complete or with major errors/flaws and no recovery is possible. Cannot fly a spacecraft. (10 - 40%)
- “√-” = assignment turned in complete. Needs a major revision but tolerable for class (but not for ops). Good enough for systems engineers. (40 - 70%)
- “√” = assignment turned in complete with average/good effort and analysis. Do an internship first, or may participate as a learner in OD team. (70 – 100%)
- “√+” = assignment turned in complete with excellent effort/analysis. A candidate to be a good Nav/OD analyst in real world. (100 - 120%)

It is expected that students will generally get a “√.” Averaging above a “√” for the term will receive all homework points.

Projects

There are nominally three projects in this course. All of them require significant analytical derivation, coding effort, and analysis. The details will be released later in the semester. See the class schedule for the timing of the projects. As mentioned earlier, the third project may be cancelled if we cannot cover the course materials fast enough or the class momentum is just not there.

Discussion/collaboration

The TAs will create a discussion board on Canvas for students to discuss the HW/projects. The instructor/TAs will not be monitoring them. We will have another discussion board on Canvas that TAs will monitor, and you can use that to ask questions that were popular in the student-only thread. Do not bombard the TAs with

every single question you have. Use your team (i.e., peers) first and think among yourselves. The instructor will not participate in any discussion on Canvas, but feel free to ask questions in/before/after class. The instructor will also not have any office hours but will communicate with the TAs often to make sure students' questions are answered. Good/hard questions will be dealt with in class by the instructor.

Important: The instructor and TAs are not your debugger. You need to debug your own code.

For *concerns* about the class (i.e., things that are not related to technical details), the instructor will be available for a meeting. It will be scheduled as requested.

Collaboration is highly encouraged and you will likely not succeed without it in class/real ops. That said, there is a clear distinction between getting help and cheating. I highly recommend thinking hard first by yourself and then use the discussion board. Don't rely on it as your cheat sheet. Otherwise you will get nothing out of this class and your character will not grow. If a student is found plagiarizing/cheating, the instructor will give an immediate F for their course grade and report to the university.

The implementation of the filtering algorithms will be difficult, and it is often the case that one indexing error or some minor error completely throws your result upside down (you will experience this at least once during the semester). Thus, I am ok that, if one is willing, that he/she shares his own code as screenshots to help other students. If you do, do this in the public domain (i.e., Canvas discussion board). That way you can understand the flow/structure of the code but you can't just copy and paste (don't use an AI tool for this). In case you got help in this way or something similar, report where you got the assistance/inspiration from in your HW/projects. Nav/OD is the team effort and you have to pay credit where it is due. Please show your respect for your fellow team members. Also, remember that the implementation must be done by yourself! It is easy to tell a good OD analyst from a bad one. Not putting in your share of effort will bite you in the future (and very badly).

Email

Do not start your email with "Hey, ...," unless you personally know the instructor/TAs. Use one of these or something more professional:

- Dr. Takahashi,
- Hi Dr. Takahashi,
- Hi Yu san,

1 University Policies

This class will be conducted in accordance with university policies:

1.1 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 (www.colorado.edu/disabilityservices/students). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see [Temporary Medical Conditions](#) under the Students tab on the Disability Services website.

1.2 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 instructors know of any such conflicts within the first two weeks of the semester so that we can work with you to make reasonable arrangements. See the [campus policy regarding religious observances](#) for full details.

1.3 Classroom and On-Campus Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. 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. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on [classroom behavior](#) and the [Student Code of Conduct](#).

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

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by 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 cureport@colorado.edu. Information about the OIEC, university policies, [anonymous reporting](#), and the campus resources can be found on the [OIEC website](#).

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

1.5 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 policy may include: 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 who are 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 academic integrity policy can be found at the [Honor Code Office website](#).

1.6 Requirements for COVID-19

All students enrolled As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu).

1.7 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.