Course offered as Special Topics for Spring 2023
AE 8803-QGU-33823 and AE 8803-GUN-31920

AE6357 Syllabus

Satellite Orbit Determination, Sections A/Q, 3 graduate credits

General Information

Description

Satellite Orbit Determination is a graduate-level course designed to provide the theoretical and practical knowledge required to precisely estimate the position of a satellite from tracking measurements. Topics covered will include statistical estimation theory, treatment of perturbing forces (drag, radiation, non-spherical Earth, etc.), time/reference systems, and satellite tracking systems (GNSS, laser ranging, optical, DSN, etc.). The focus is on the practical understanding and application of the material to earth and planetary missions, as well as topics in space domain awareness.

Pre- &/or Co-Requisites

Basic knowledge of satellite orbits, probability/statistics, linear algebra, and Matlab programming.

Course Goals and Learning Outcomes

Students completing this course will gain knowledge in the following topics:

- The development and application of linear unbiased minimum variance estimation techniques
- The treatment of perturbing forces on orbiting objects, e.g., drag, radiation pressure, non-spherical gravity, etc.
- Understand the importance of time and reference systems to precise orbit determination
- A review of the various tracking methods currently in use for tracking objects in near-Earth and deep-space environments, e.g., GNSS, laser ranging, optical, DSN, etc.
- Understand the various physical measurements used by these tracking systems, and how they are processed to generate spacecraft position and velocity estimates
- Conduct practical exercises using both simulated and real data sets
- Gain exposure to the wide range of applications and uses of satellite orbit determination, and how the course material is applied to Earth and planetary missions, space domain awareness, and more.

Course Requirements & Grading

Assignment	Date	Weight (Percentage, points, etc)
Homeworks	Bi-weekly	35% (approximately 5.8% per homework)
Mid-term exam	Mid-semester	25%
Final project	Last class day	40%

Description of Graded Components

Homework: Homework is assigned to provide students with an opportunity to apply the theoretical material discussed in the lectures to practical applications. Homework dissemination, submission, and due dates will be managed electronically via Canvas. Late homework will in general not be accepted without prior approval. In-class verbal or Canvas due date announcements override projected dates in the lecture plan. Homework should be professional, legible, indicate units, and sufficiently describe all important steps in a solution.

Your final answer for each problem should be boxed or otherwise clearly indicated. Electronic submissions will be done via Canvas, and should also include any source code used to obtain your solutions (if applicable). Deductions will be made for incomplete solutions and improper formats. Details on submission instructions will be provided in the homework assignment description. Note that some assignments will require heavy use of Matlab, and that **students are responsible for familiarizing themselves with Matlab.**

Exams: As with homework solutions, exam solutions should be legible, include units, and sufficiently describe all important steps in a solution. Put your name and page number on each page, and 'box' your final answer for each problem. Deductions will be made for incomplete solutions and improper formats. Additional instructions and restrictions for each exam will be discussed in class and will be clearly identified on the exam coversheet. In general, exams are closed-book, meaning that you are to complete the exam without the aid of textbooks, hand-outs, notes, cellular telephones, personal digital devices, or computers/software. Use of a pocket (non-programmable) calculator is allowed.

Final Project: A final project will be assigned after the mid-term exam and is designed to give everyone the opportunity to apply the course material to a topic of your choice. More detail will be provided on the scope and content of the report, but the final report should emulate a journal-style manuscript in both style and format. The report will be assessed on the relevance, novelty, and technical quality of the analysis done, as well as the presentation of the results in the report (a formal grading rubric will be provided).

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Full credit is awarded for solutions that are correct and demonstrate an understanding of the concepts of the problem. Partial credit is given for solutions that, while incorrect, demonstrate some knowledge of the concepts. Final grades may be curved based on overall class performance.

Course Materials

Course Text

1. Tapley, Schutz, and Born, *Statistical Orbit Determination*, Elsevier, 2004 (eBook available at no cost via GT Library)
2. Montenbruck and Gill, *Satellite Orbits: Models, Methods and Applications*, Springer, 2000 (Corrected 4th Printing 2012)

Additional Materials/Resources

1. Teunissen and Montenbruck, *Springer Handbook of Global Navigation Satellite Systems*, Springer 2017 (eBook available at no cost via GT Library)
2. Hofmann-Wellenhof, Lichtenegger, and Wasle, *GNSS – Global Navigation Satellite Systems: GPS, GLONASS, Galileo, and more*, Springer, 2008 (eBook available at no cost via GT Library)
3. Borre and Strang, *Algorithms for Global Positioning*, Wellesley-Cambridge, 2012
4. Moyer, T.D., "Formulation for Observed and Computed Values of Deep Space Network Data Types for Navigation", JPL Publication 00-7, 2000 (available at no cost online)
5. Miller, J., "Planetary Spacecraft Navigation," Springer, 2019 (eBook available at no cost via GT Library)

Course Website and Other Classroom Management Tools

Course materials will be posted online to Canvas (https://canvas.gatech.edu/). Course materials (e.g. recorded videos) will be available to both in person and distance learning sections. Important communications

to the class will be sent through the Canvas system; please be alert to these messages. Students will be held responsible for any message or announcement that has been posted to the class for more than 24 hours.

Course Expectations & Guidelines

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Attendance and/or Participation

Classroom attendance, either in person or remotely, is strongly encouraged but not required. Active participation is essential for understanding major concepts and contributing to the learning of others.

Absences related to personal illness or emergency, or career development (e.g. presenting a paper at a conference or scheduled job interview) are considered excused. Please contact the instructor as soon as you know of a schedule conflict if this applies to you. Please see the Institute Absence Policy - https://catalog.gatech.edu/rules/4/ for more information.

Collaboration & Group Work

Discussions with other students about how to solve homework problems are allowed and encouraged; however, all work turned in must be the student's own original work.

The use of outside references (e.g. textbooks) is expected and encouraged; when appropriate cite any referenced material that is used.

Use of homework solutions from prior semesters (if/when applicable) is not allowed.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

Homework assignments are due at the designated time using online submission on Canvas. Late homework will in general not be accepted without prior approval. Under special circumstances and coordination in advance with the professor, exams may be rescheduled for an individual. Exams missed due to illness or other emergencies can be made up, but must be supported by appropriate documentation coordinated through the Dean of Students. The professor reserves the right to grant special dispensations when deemed appropriate.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions

will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Student Use of Mobile Devices in the Classroom

Mobile Devices (laptop computers and tablets) may be used in class to enhance your learning experience, provided they are used in support of the class and are not a distraction to you or your classmates. Viewing materials unrelated to the class and doing homework in class is not allowed. Cell phones should be set to silent mode during class. If you must answer a phone call during class, please step outside so as not to disturb the class.

Additional Syllabus Components

Honesty:

The School of Aerospace Engineering values honesty and integrity of all members of our community. An important element of this value is the academic honor code.

Georgia Tech Honor Challenge Statement: I commit to uphold the ideals of honor and integrity by refusing to betray the trust bestowed upon me as a member of the Georgia Tech community.

Honor Code: http://policylibrary.gatech.edu/student-affairs/academic-honor-code#Article_I:Honor_Agreement

Well Being:

The School of Aerospace Engineering values the complete well-being of all members of its community, which includes professional, physical, spiritual, emotional, and social dimensions. There are numerous resources to support the health and well-being of all members of our community: https://gatech.instructure.com/courses/108574

Mental Health Resources:

Emergencies: Can either Call 911 or call Campus Police at 404.894.2500 http://www.police.gatech.edu/
Center for Assessment, Referral, & Ed. (CARE): https://care.gatech.edu/ 404.894.3498 (Counselor On-Call)
Counseling Center: https://counseling.gatech.edu/ 404.894.2575
Stamps Health Services: https://health.gatech.edu/ 404.894.1420
Student Life and Dean of Students: https://studentlife.gatech.edu/content/get-help-now 404.894.6367
Victim-Survivor Support (VOICE): https://healthinitiatives.gatech.edu/well-being/voice 404-385-4464/(or 4451)
National Suicide Prevention Lifeline: 1.800.273.TALK (8255)
Georgia Crisis and Access Line: 1.800.715.4225

Social Justice:

The School of Aerospace Engineering values social justice for all members of the Georgia Tech community and the larger society. Social justice means that everyone's human rights are respected and protected. We stand committed in the fight against racism, discrimination, racial bias, and racial injustice. Our shared vision is one of social justice, opportunity, community, and equity. We believe that the diversity and contributions from all of our members are essential and make us who we are. We believe that our impact must reach beyond the classroom, research labs, our campus, and the technology we create, but must also improve the human condition where injustice lives. We will continue to work to understand, value, and celebrate all people and create an inclusive educational and work environment that welcomes all.

As a matter of policy, Georgia Tech is committed to equal opportunity, a culture of inclusion, and an environment free from discrimination and harassment in its educational programs and employment. Georgia Tech prohibits discrimination, including discriminatory harassment, on the basis of race, ethnicity, ancestry, color, religion, sex (including pregnancy), sexual orientation, gender identity, national origin, age, disability, genetics, or veteran status in its programs, activities, employment, and admissions.

http://policylibrary.gatech.edu/equal-opportunity-nondiscrimination-and-anti-harassment-policy

Course Schedule

The projected lecture plan, midterms, and holidays are summarized below. With the exceptions of holidays and the final exam period, all of these dates are subject to change. The instructor reserves the right to make changes to the projected lecture plan, including changing exam dates, homework assignment dates, and homework due dates.

Wk	Topic	Book	
1	Intro; syllabus; OD overview/example;	TSB 4.3	
2	Linear unbiased minimum variance estimate (LUMVE)	TSB 4.4, App A, B	
2	LUMVE cont'd	TSB 4.4	
3	LUMVE cont'd, w/apriori	TSB 4.4	HW 1 out
3	Dynamical systems		
4	Batch estimation		
4	Batch cont'd; State Transition Matrix	TSB 4.8	
5	Batch estimation examples	TSB 4.6	HW 1 due; HW 2 out
5	Batch w/apriori; shifting	TSB 4.6, MG 8	
6	The orbit problem	TSB 4.6, MG 8	
6	Force models (gravity, SH, 3rd body, SRP, drag, tides, relatvistic effects, etc.)	TSB 4.6, MG 8	
7	Force models cont'd	TSB 2, MG 3	HW 2 due; HW 3 out
7	Time systems (history, definitions, time systems overview, relativity)	MG 3, TSB 2	
8	Time systems (history, definitions, time systems overview, relativity)	MG 3, TSB 2	
8	Reference systems/frames (celestial, terrestrial, local, nutation, precession); vertical height systems	MG 5	
9	Reference systems/frames (celestial, terrestrial, local, nutation, precession); vertical height systems	MG 5	HW 3 due
9	Tracking systems (range, range-rate, angles, SLR, DORIS, GNSS)	MG 6, TSB 3	
10	Tracking systems (range, range-rate, angles, SLR, DORIS, GNSS)	MG 6, TSB 3	
10	GNSS Fundamentals	Notes	HW 4 out
11	GNSS Fundamentals	Notes	
11	GNSS-based OD	Notes	
12	GNSS-based OD	Notes	HW 4 due; HW 5 out
12	Planetary OD - DSN	Notes	
13	Planetary OD - DSN	Notes	
13	Planetary OD - Optical	Notes	
14	Planetary OD - Optical	Notes	HW 5 due; HW 6 out
14	Planetary OD - Optical	Notes	
15	Planetary OD - Optical	Notes	
15	Overflow/additional topics	TBD	
16	Overflow/additional topics	TBD	HW 6 due
16			Final Project Due
17			Grades Due