AE 8803 LIG AND QLI—SPACECRAFT ATTITUDE ESTIMATION AND CONTROL

Course Syllabus – Spring 2022

Instructor:	Prof. Glenn Lightsey, glenn.lightsey@gatech.edu
Teaching Assistant:	Alex Sanchez, asanchez46@gatech.edu
Course Lecture:	5:00 – 6:15p Tuesday and Thursday
Course Location:	Manufacturing Related Disciplines Complex (MRDC) 2404
Office Hours:	Lightsey: 3:00 – 4:00p Monday, ESM 110A and BlueJeans (remote) Sanchez: 2:00 – 3:00p Friday, BlueJeans (remote)
Catalog Description:	Attitude representations, dynamics, estimation, and control. Spacecraft attitude sensors and actuators. Attitude determination and control topics applied to spacecraft and space missions. Special cases and applications.
Required Text:	Markley and Crassidis, Fundamentals of Spacecraft Attitude Determination and Control, Springer, 2014. Reading and homework will be assigned from this text.
Optional Texts:	The following textbooks may be helpful as optional references for this course: (1) Schaub and Junkins, Analytical Mechanics of Space Systems, 4th edition, AIAA, 2018. (2) Hughes, Spacecraft Attitude Dynamics, Dover, 2004.

Grading:

Homework:	42%	(6 total due every two weeks)
In Class Midterm Exam:	23%	
Final Project:	35%	(due on last class day)
Total	100%	

- Homework assignments are due at the designated time (usually 5:00 pm) using online submission on Canvas. Any assignment turned in after collection is late.
- Late homework assignments may be turned in during the advertised grace period (usually 48 hours) for half credit. Any homework turned in after this is not counted.
- Students in the distance learning section (QLI) will operate with the standard 1-week delay in assignment due dates.
- A final project will be given in place of a final exam. The final project will be handed out approximately one week before the end of the semester and will be due on the final class day. The final project is to be completed individually without consultation with other students.
- Final course letter grades may be curved at the discretion of the Instructor.

Course Website: 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.

Lectures: Lectures will be conducted synchronously with in-class and remote participation. Attendance in person or remotely is encouraged but is not required. Due to Covid-19 precautions, face masks are strongly recommended for in person attendance. Lectures will be recorded and posted on Canvas so they may be played back asynchronously. Students are expected to keep pace as the homework assignments will be based on the current lectures.

Piazza: Find our class signup link at: https://piazza.com/gatech/spring2022/ae8803qliqnu.

We will be using Piazza for discussion outside of class. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com.

Attendance: Classroom attendance, either in person or remotely, is strongly encouraged. Participation is essential for understanding major concepts, and attendance may also be considered by the instructor in assigning final grades close to a letter grade boundary, e.g. assessing whether or not to round up.

Distance Learning: Students in the distance learning section (QLI) will operate with the standard 1-week delay. The midterm exam will require a proctor, per DLPE procedures.

Honor Code: Students are required to adhere to the GT Academic Honor Code (http://www.honor.gatech.edu). Please note the following specific policies:

- 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.
- Use of homework solutions from prior semesters (if/when applicable) and/or use of other printed or online solutions that are not the student's original work is not allowed.
- The midterm exam and final project are intended to measure the learning of individual students; therefore receiving assistance from other individuals during exams is not allowed.
- Stand-alone calculators are allowed, but smart phones, laptops, and other electronic devices may not be used during the midterm exam. Equations may not be programmed into calculators before exams. Additional details regarding exam content and rules will be provided by the instructor prior to the exam.
- Students are required to report any suspected violation of the Honor Code to the Instructor, whether or not they were directly involved in the incident.
- At the discretion of the Instructor, suspected violations of these or any other Academic Honor Code policies will be reported to the Office of Student Integrity for investigation.

Course Topic Outline

The following outline lists the topics to be covered in the course and tentative dates for exams. Changes to the outline will be discussed in class, and updated versions will be uploaded as necessary to Canvas.

Lecture	Date	Topic	Homework
1	1/11	Introduction	H1 assigned
2	1/13	Euler's Theorem	
3	1/18	Quaternions	
4	1/20	Rodrigues Parameters	
5	1/25	Kinematics	H1 due, H2 assigned
6	1/27	Attitude Rates	
7	2/1	Star Cameras and Sun Sensors	
8	2/3	Magnetic Sensing and Calibration	
9	2/8	Magnetic Actuation and Stabilization	H2 due, H3 assigned
10	2/10	Gravity Gradient Dynamics	
11	2/15	Gravity Gradient Stabilization	
12	2/17	Wheels and Momentum Management	
13	2/22	Midterm Review, Q&A	H3 due
14	**2/24**	**Midterm Exam in class**	
15	3/1	Momentum Biased and Zero Momentum Spacecraft	H4 assigned
16	3/3	Control Moment Gyros	
17	3/8	Attitude Estimation: TRIAD and Davenport's method	
18	3/10	Schuster's QUaternion ESTimator (QUEST)	
19	3/15	Multiplicative Extended Kalman Filter (MEKF)	H4 due, H5 assigned
20	3/17	Gyroscopes, Drift, and Calibration	
	3/22	**Spring Break – no class**	
	3/24	**Spring Break – no class**	
21	3/29	Multisensor Fusion Attitude Estimation	
22	3/31	Single Input Single Output (SISO) Attitude Control	
23	4/5	Linear Quadratic Regulator (LQR) Attitude Control	H5 due, H6 assigned
24	4/7	Spacecraft Attitude Regulation	
25	4/12	Sliding Mode Attitude Control (Nonlinear Control)	
26	4/14	Spacecraft Thruster Attitude Control (Nonlinear Control)	
27	4/19	Course Review, Q&A	H6 due
28	**4/21**	**Final Project Assigned**	Final Project Assigned
29	**4/26**	**Final Project Due***	Final Project Due

*The Final Project will be due during the 'Final Instructional Class Days' unless otherwise announced by the instructor.

Covid-19 Related Considerations

The spring semester 2022 is especially challenging due to the Covid-19 pandemic. The following information relates to specific services and guidelines for courses during this semester. The most up-to-date information on Covid-19 is on the TECH Moving Forward website and in the Academic Restart Frequently Asked Questions.

Instructor Illness or Exposure to Covid-19

During the spring 2022 semester, some faculty members may be required to quarantine due to exposure or isolate due to a Covid-19 diagnosis. Some disruption to classes or services is inevitable, but Georgia Tech is making every effort to ensure continuity of operations. As is the case in any semester, faculty may cancel a class if they have an illness or emergency situation and cover any missed material at their own discretion. If an instructor needs to cancel a class, they should notify students as early as possible.

Faculty who are staying home due to symptoms should monitor their health closely and consult with their school chair to determine if remote instruction or substitute instruction is most appropriate for the course. If they need to cancel a class repeatedly, a backup will be supplied in the form of a temporary substitute instructor or asynchronous work. No course will be canceled after the first class has occurred.

If you have not tested positive but are ill or have been exposed to someone who is ill, please follow the Covid-19 Exposure Decision Tree for reporting your illness.

Student Illness or Exposure to Covid-19

During the semester, you may be required to quarantine or self-isolate to avoid the risk of infection to others. Quarantine is the separation of those who have been exposed to someone with Covid-19 but who are not ill; isolation is the separation of those who have tested positive for Covid-19 or been diagnosed with Covid-19 by symptoms.

If you have not tested positive but are ill or have been exposed to someone who is ill, please follow the Covid-19 Exposure Decision Tree for reporting your illness.

During the quarantine or isolation period you may feel completely well, ill but able to work as usual, or too ill to work until you recover.

Remote courses and remote class sessions during hybrid courses. Unless you are too ill to work, you should be able to complete your remote work while in quarantine or isolation.

In-person courses and in-person class sessions during hybrid courses. When in isolation or quarantine you will be unable to attend in-person course sessions but your instructor may require you either to participate in the course remotely, complete some complementary work that parallels what you are missing in class, or make up some class work when you return.

If you are ill and unable to do course work this will be treated similarly to any student illness. The Dean of Students will have been contacted when you report your positive test or are told that it is necessary to quarantine and will notify your instructor that you may be unable to

attend class events or finish your work as the result of a health issue. Your instructor will not be told the reason. We have asked all faculty to be lenient and understanding when setting work deadlines or expecting students to finish work, and so you should be able to catch up with any work that you miss while in quarantine or isolation. Your instructor may make available any video recordings of classes or slides that have been used while you are absent, and may prepare some complementary asynchronous assignments that compensate for your inability to participate in class sessions. Ask your instructor for the details.

CARE Center, Counseling Center, Stamps Health Services, and the Student Center

These uncertain times can be difficult, and many students may need help in dealing with stress and mental health. The **CARE Center** and the **Counseling Center**, and **Stamps Health Services** will offer both in-person and virtual appointments. Face-to-face appointments will require wearing a face covering and social distancing, with exceptions for medical examinations. Student Center services and operations are available on the **Student Center** website. For more information on these and other student services, contact the Vice President and Dean of Students or the **Division of Student Life**.

Georgia Tech School of Aerospace Engineering Values

Discussion Points

1. **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

2. **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

   COVID-19 Safety: Vaccinate, Mask, Test
   GT Safety Guidelines: https://health.gatech.edu/tech-moving-forward
   Current guidance is summarized below, but continue to follow the site above and other Institute communications in case changes occur:

   - If there is one thing each one of us can do to protect ourselves and keep others safe, it is to get vaccinated. The new vaccines have proven to be extraordinarily effective at preventing severe illness. Getting vaccinated at Georgia Tech easy and free.

   - At Georgia Tech, everyone is encouraged to wear a mask or face covering while inside campus facilities.

- The free asymptomatic surveillance testing program remains available to all students and employees. You may participate in regular testing even if you have been fully vaccinated. We especially encourage those who have not been vaccinated to get tested weekly.

3. **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