16.685: Spacecraft Attitude Determination and Control

Spring 2026

Course Description

This course is all about attitude: pointing, slewing, spinning, and (occasionally, but hopefully not too often...) tumbling. We will discuss:

- Attitude representations and how to effectively parameterize attitude in different situations.
- How to model and simulate spacecraft attitude dynamics.
- How to estimate attitude from sensor measurements.
- How to manage a spacecraft's attitude both with passive physics and closed-loop control.

The course will be based around a project in which each student analyzes the attitude determination and control system (ADCS) for a spacecraft mission.

Prerequisites: Strong linear algebra skills, experience with a high-level programming language like Python, MATLAB, or Julia, and basic familiarity with ordinary differential equations.

Instructor

Prof. Zac Manchester **Email:** zacm@mit.edu **Office:** 16-243

Logistics

- Lectures will be held TODO: time Eastern time in TODO: place. Lectures will also be live streamed on zoom and recorded for later viewing.
- Office hours will be TODO: based on survey.
- Homework assignments will be due by TODO: due date. Two weeks will be given to complete each assignment.
- Short quizes will occasionally be assigned to assess student comprehension. These will be graded only based on completion.+
- Slack will be used for general discussion and Q&A outside of class and office hours.
- There will be no exams. Instead, students will compile a final report based on analysis done in each homework assignment.

Learning Objectives

By the end of this course, students should be able to do the following:

1. Model and simulate the attitude dynamics of a spacecraft
2. Analyze stability of spacecraft attitude dynamics
3. Estimate the attitude of a spacecraft from sensor measurements
4. Design feedback controllers to stabilize spacecraft attitude
5. Design slewing maneuvers to point a spacecraft at a desired target
6. Characterize the performance of a closed-loop attitude control system
7. Select sensors and actuators to meet mission requirements

Learning Resources

There is no textbook for this course. Video recordings of lectures and lecture notes will be posted online. The following books are good references for some of the topics discussed in the course that you may want to refer to, but are not required:

1. P. Hughes, *Spacecraft Attitude Dynamics*, Dover, 2004.
2. F. Markley and J. Crassidis, *Fundamentals of Spacecraft Attitude Determination and Control*, Springer, 2014.
3. J. Wertz, *Spacecraft Attitude Determination and Control*, Kluwer, 1978.

Assignments

Every two weeks students will be asked to complete a homework assignment that includes analysis of some aspect of the ADCS design for their chosen spacecraft mission. A write-up of this analysis will be reviewed by the instructor and feedback will be returned to students the following week. At the end of the semester, these assignments will be compiled into a final report. There will be no exams in this course.

Grading

Grading will be based on:

- 50% Final Report
- 40% Homework
- 5% Quizes
- 5% Participation

Attendance during lectures is not required to earn a full participation grade. Students can also participate through any combination of office hours, Slack discussions, project presentations, and by offering constructive feedback about the course to the instructors.

Course Policies

Late Homework: Students are allowed a budget of 5 late days for turning in homework with no penalty throughout the semester. They may be used together on one assignment, or separately on multiple assignments. Beyond these six days, no other late homework will be accepted.

Tentative Schedule

Week	Dates	Topics	Assignments
1	Feb 3	Course Overview, & Attitude Intro	Survey
	Feb 5	Representations, SO(3), and Quaternions	HW1 Out
2	Feb 10	Rigid Body Dynamics	
	Feb 12	Gyrostat Dynamics	
3	Feb 17	Damping and Environmental Perturbations	HW1 Due
	Feb 19		HW2 Out
4	Feb 24	Spinning Spacecraft and Stability	
	Feb 26	Numerical Simulation	
5	Mar 3	Attitude Determination Sensors	HW2 Due
	Mar 5	TRIAD	HW3 Out
6	Mar 10	Statistical Estimation	
	Mar 12	Optimizing with Attitude	
7	Mar 16	Wahba's Problem	HW3 Due
	Mar 18	Nonlinear Least-Squares & Convex Relaxations	
8	Mar 24	No Class	
	Mar 26	No Class	
9	Mar 31	Kalman Filters	HW4 Out
	Apr 2	Multiplicative & Invariant EKF	
10	Apr 7	Passive Attitude Control Methods	
	Apr 9	Attitude Control Actuators	
11	Apr 14	Feedback Controllers	HW4 Due
	Apr 16	Stabilization and Tracking	HW5 Out
12	Apr 21	Designing Slew Maneuvers	
	Apr 23	Optimal Control	
13	Apr 28	Performance Analysis	HW5 Due
	Apr 30	Calibration	
14	May 5	Advanced Topics	
	May 7	Case Studies	
14	May 12	Case Studies	