

16/18-873: Spacecraft Design-Build-Fly Lab

Fall 2023 – Spring 2024

Course Description

Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This capstone design class brings together the material from prior classes in a way that emphasizes the interactions between disciplines and demonstrates how some of the more theoretical topics are synthesized in the practical design of a spacecraft. The class will design, build, and test a small satellite that addresses objectives and requirements posed at the beginning of the course sequence. Students will work in subsystem teams, each focusing on some aspect of the spacecraft, but exposed to many different disciplines and challenges. Practical, hands-on engineering skills will be emphasized, along with fabrication and testing of physical hardware and the creation of thorough documentation.

Instructors

Prof. Zac Manchester	Email: zacm@cmu.edu
Prof. Brandon Lucia	Email: blucia@cmu.edu
TA: Brad Denby	Email: bdenby@cmu.edu
TA: Neil Khera	Email: nkhera@andrew.cmu.edu

Learning Objectives

The goal of this course is to give students hands-on experience designing and building small spacecraft subsystems and integrating them into a CubeSat. Throughout this course, students will:

1. Understand how the design and integration of a system whose performance depends on the success of many interacting subsystems.
2. Work within a small team to fabricate, and test hardware and software through rapid design iteration.
3. Coordinate with other teams to integrate subsystems into a complete spacecraft.
4. Gain exposure to the complete life cycle of a small satellite mission.

Logistics

The course will involve designing and building hardware in small teams. Class time will be used primarily for weekly team meetings and consulting time to meet with the instructors.

- Lectures on selected topics will be held at 3:40 on Mondays, followed by consulting hours.

- All-hands meetings will be held at 3:40 on Wednesdays, followed by consulting hours.
- Sub team meetings will be held once per week at times coordinated with the instructor.
- Attendance of weekly team meetings is mandatory.
- Slack will be used for coordination between teams and instructors. All students will be added to the “SpacecraftDesignBuildFlyLab” slack channel.
- GitHub will be used to manage project files for all teams.

Assignments and Exams

There will be no exams in this course. Evaluation will be based on participation, contribution to design and fabrication work, and final documentation from each team.

Grading

Grading will be based on:

- 25% Participation and attendance of team meetings
- 25% Individual technical contributions quantified by git commit history and peer surveys
- 15% Completeness and quality of documentation
- 10% Outcome of design review

Learning Resources

There is no textbook required for this course. Video recordings of lectures and lecture notes will be posted online. Additional references for further reading will be provided with each lecture.

Course Policies

Attendance: This is a team-based course. In order to coordinate work among teams, participation in weekly meetings is required. If you are unable to be present at a meeting, you must notify the instructors and ensure that your teammates are prepared to present your work.

Accommodations for Students with Disabilities: If you have a disability and are registered with the Office of Disability Resources, I encourage you to use their online system to notify me of your accommodations and discuss your needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

Statement of Support for Students’ Health & Well-Being: Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep, and taking some time to relax. This will help you achieve your goals and cope with stress.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit <http://www.cmu.edu/counseling>. Consider reaching out to a friend, faculty, or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922

Re:solve Crisis Network: 888-796-8226

If the situation is life threatening, call the police:

On campus: CMU Police: 412-268-2323

Off campus: 911

Tentative Fall 2023 Schedule

Week	Dates	Topics	Assignments
1	Jan 17 Jan 19	Course Overview, & Dynamics Intro Stability, Discrete-Time Dynamics	Survey HW0 Out
2	Jan 24 Jan 26	Optimization Intro Numerical Optimization Pt. 1	HW0 Due HW1 Out
3	Jan 31 Feb 2	Numerical Optimization Pt. 2 & Optimal Control Intro Pontryagin, Shooting Methods, & LQR Intro	
4	Feb 7 Feb 9	LQR as a QP & Riccati Equation No Class	HW 1 Due HW 2 Out
5	Feb 14 Feb 16	Dynamic Programming & Intro to Convexity Convex Model-Predictive Control	
6	Feb 21 Feb 23	Intro to Trajectory Optimization, Iterative LQR, & DDP DDP with Constraints and Free Final Time	HW2 Due HW3 Out
7	Feb 28 Mar 2	Direct Trajectory Optimization, Collocation, & SQP Attitude Intro: SO(3) & Quaternions	
8	Mar 7 Mar 9	No Class No Class	
9	Mar 14 Mar 16	Optimizing with Attitude LQR with Attitude, Quadrotors, & Contact Intro	HW3 Due HW4 Out
10	Mar 21 Mar 23	Trajectory Optimization for Hybrid Systems Data-Driven Methods & Iterative Learning Control	
11	Mar 28 Mar 30	Stochastic Optimal Control & LQG Robust Control & Minimax DDP	HW4 Due
12	Apr 4 Apr 6	RL from an Optimal Control Perspective Practical Tips & Tricks, Control History	
13	Apr 11 Apr 13	Case Study: How to Land a Rocket No Class	
14	Apr 18 Apr 20	Case Study: How to Drive a Car Case Study: How to Walk	
14	Apr 25 Apr 27	Project Presentations Project Presentations	