ASEN 3128 Aircraft Dynamics

Syllabus

Lecture:	AERO 120	TTH	4:00 – 5:15 pm
Lab:	AERO 141	Tues	12:30 – 2:20 pm
	AERO 141	Wed	10:30 – 12:20 pm
	AERO N100	Thurs	10:30 – 12:20 pm

Instructors

Prof. Eric Frew
Office: AERO 269 Phone: (303) 735-1285 Email: eric.frew@colorado.edu
Office Hours: Mon 4-5 PM

Prof. Zachary Sunberg
Office: AERO 263 Phone: (303) 735-0078 Email: zachary.sunberg@colorado.edu
Office Hours: TBD

Teaching Fellows

Alex Hirst Camron.Hirst@colorado.edu
Dominic Hernandez Dominic.Hernandez@colorado.edu
Madison Ritsch Madison.Ritsch@colorado.edu
Riana Gagnon riana.gagnon@colorado.edu
Daniel Mathews Daniel.Mathews@Colorado.edu

Text

Required: *Dynamics of Flight: Stability and Control,* Bernard Etkin and Lloyd Reid, John Wiley and Sons. 3rd Ed., 1996

Prerequisites

ASEN 2002, 2003, 2004, and APPM 2360 (min grade C).

Overview

This course covers the key ideas that enable an understanding of how aircraft work and tools for quantitative analysis and design methods to achieve specified dynamical behavior. Because aircraft exist in many different forms, and new designs continue to be developed, the focus is on the common principles that underlie atmospheric flight, so that a solid basis can be formed for future work in most any direction. Concrete treatment of these ideas, tools, and methods is

provided through working problems in assigned groups, consisting of analysis, simulation, and design problems, including development of MATLAB simulation models for two very different vehicles: a quad-copter and a conventional airplane.

In their full expression, aircraft dynamics possess astounding complexity, and it is a tribute to the ideas developed by aviation's pioneers that a relatively simple understanding can often be obtained, leading to clear insights and design principles. While these concepts are not inherently difficult, they do lie outside most common experience, and they depend on new nomenclature and strange notation that can seem overwhelming at first. It is only through diligent and careful use of this new language that the underlying simplicity can be grasped and conveyed on exams; mastery of the language of aircraft dynamics is perhaps the most important predictor for success in the course.

The course has been designed to develop a conceptual grasp of the key ideas below, and to demonstrate proficiency in using these concepts to solve problems, construct and validate simulations, and to explain behaviors and results obtained. In particular, engineering reasoning skills using these concepts are stressed in assignment solutions and examinations. The key learning objectives are:

Vector mechanics

- Vector representation in coordinate frames
- Change of coordinate frame representation (coordinate rotation)
- Relative motion, frame derivatives
- Change of derivative frame: velocity rule

How aircraft dynamics models are created and what the terms mean

- 3D rigid body translational model
    - Kinematics
    - Dynamics, external forces
    - Effects of wind
- 3D rigid body rotational model
    - Kinematics, Euler angle attitude representation
    - Dynamics, Euler moment equations, external moments
- External forces and moments
    - Aerodynamic effects
    - Control effects
    - Steady flight conditions, trim states

How aircraft dynamics models are simulated

- State space models
- Matlab integration
- Good naming and commenting habits

How dynamical behavior is understood and specified

- Linearization
- Decoupling
- Stability derivatives
- Modal solutions
- Stability characterizations
- Modal specifications

How feedback control is designed to meet behavioral objectives

- Sensor selection, control structure
- Effects on mode eigenvalues

Course Components

Material and concepts are introduced, and student mastery is evaluated using several mechanisms throughout the course:

Reading – The textbook provides the essential basis for the course, including the concepts, terminology, notation, methods, and examples used to convey the course topics. Specific reading assignments will be given covering key sections of the book; some book sections are not covered in the course. Some supplementary material will also be provided. The textbook contains a wealth of information, but the concepts and notation are new to most: some sections need to be read more than once to fully grasp the material.

Lectures – These are intended to emphasize key ideas and methods that make the material easier to grasp. They are therefore a counterpart to the reading, not a replacement. The value of lectures is dependent on your participation in them. Passive "watching" will provide little benefit. Active note taking is critical to developing first-hand familiarity with the notation, terminology, and methods, and to gaining comfort in using them. Although lectures will be recorded, this is a poor substitute for your own lecture notes. Questions are encouraged during lectures and will be prompted often. Lectures will be recorded using the Classroom Capture system and/or another system, and will be accessible through Canvas. We will not offer live, online participation in class.

Homework – Homework problems are assigned every other week, out of sync with the lab assignments. They provide practice in solving problems of varying difficulty and sometimes will also involve computing. Collaboration on homework is allowed (copying is not); however, students are encouraged to use homework as a means to ensure their individual mastery of the

subject. In class group problem solving and labs will allow for considerable collaborative problem solving. Homework assignments are submitted by uploading a pdf to Gradescope.

Reading Quizzes – These will cover the reading material, lectures, and portions of the lab assignments. Quiz grades will contribute to your individual course grade and are designed to encourage you to come to class and lab prepared. They will consist of multiple-choice questions similar in format to questions that will be on the exams. In most cases the Reading Quizzes will cover material in the reading assignments before it is covered in lecture. In some cases the quiz questions will draw from material covered in previous courses like ASEN 2003.

Lab Assignments – These provide first-hand experience employing the reading and lecture material. They consist of analysis and computation exercises, simulation development, and simulation use to address aircraft stability and control design problems. Assignments will be carried out in small groups. Students are expected to use these assignments and the associated group learning opportunities to strengthen their individual mastery of the subject. Dividing up the learning on assignments by dividing up the work is a recipe for failure on the individual exams in this course.

Proper presentation of engineering work is important throughout the ASEN curriculum, as in professional life thereafter, and students are expected to properly describe what was done and explain results using graphical and written descriptions based on the precise terminology and notation introduced in the course.

A secondary objective of the Lab Assignments is the development of proficiency with numerical simulation, and to develop good programming habits. Simulation is becoming an indispensable tool in engineering, and proficiency is expected of professionals in this field.

Exams – These are the primary means of evaluation of your individual grasp of the course material. Two in-class written exams will be conducted. Exams will include both conceptual questions and quantitative problems. Precise use of terminology and notation is stressed. The final exam is comprehensive in that it will contain material from the entire course, but emphasis will be placed on the final section of the course material.

Logistics

1. **Office hours** are scheduled to provide dedicated time for student questions and feedback. Students are encouraged to come to office hours with questions regarding course material, homework, lab assignments, etc. The instructor will hold one hour per week and the TAs will hold one hour per week, in addition to the department Study Hall. Private meetings with instructors or TAs can also be arranged if needed. The date and time for office hours may change when the instructors switch in the middle of the semester.

2. **Study Hall**: In order to improve academic support, provide peer mentorship, and build community for undergraduate students the Aerospace department is launching the Undergraduate Study Hall program. During Study Hall course TAs and Engineering Fellows will be available to provide support. The Study Hall for ASEN 3128 will be

Thursday, 5-7 PM (Starting on 3rd week of fall semester) in AERO N240 and AERO N250.

3. **Discussion Board**: A workspace for ASEN 3128 was create on the Ed platform to facilitate interaction and discussion between students, instructors, and TAs. Students will receive an email invitation to join the workspace or they can follow this link: https://edstem.org/us/join/jN2ekx. The discussion board should be used for questions about the course and material that is likely to be relevant to the entire class.

4. **Email questions**: Students are able to email the instructor questions throughout the week regarding course material. DO NOT expect an immediate response. Any question received by 2PM should receive a response by 5PM the same day. Questions received after 2PM may not receive a response until 5PM the next day.

5. **Attendance** at all lectures and lab sessions is essential. Students who come to class prepared and participate in discussions typically have a more rewarding experience. Attendance at lab sections is equally important. The instructors and TAs will be available for all lab sessions, and the individual assistance this affords can be extremely valuable.

6. **Taking your own notes**: Firsthand contact with the notation and diagrams is key to understanding the material in this course, and to conveying your understanding on exams. Lectures will be recorded for repeated viewing, to ensure details are not missed. But there is no substitute for taking your own notes.

7. **Homework** - Collaboration is permitted on homework. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy solutions from classmates or from Internet resources. The work that you turn in must be your own--copying is not allowed for any assignments. Students who are caught copying homework solutions will be reported for violation of honor code and may incur both academic and non-academic sanctions. Homework is submitted individually through Gradescope. Please indicate clearly where each problem begins and ends. (You do not need to use a separate sheet for each problem.) Written work must be neat and readable with adequate spacing and margins. Final answers must be indicated with an arrow, underline, or box. Very messy work will not be graded and a score of zero recorded.

8. **Reading Quizzes** will be given weekly in an on-line format through Canvas. These will cover the reading material, lectures, and portions of the Lab Assignments. Quiz grades will contribute to your individual course grade. Reading quizzes are administered through Canvas every Wednesday/Thursday, except on days where there is an exam. Quizzes will be available to take from Wednesday at 5:00 PM until 3:00 PM on Thursday. Students will have 30 minutes to take the Reading Quiz once it has been started.

9. **Examinations & Comprehensive Final** - Exams will be given during the class periods. The final exam is scheduled according to University policy. Any type of collaboration or copying on an exam, or final constitutes cheating and will result in an F for the course. An honor code violation or accusation report will be filed. **There will be a statute of**

limitations on when exam grades can be corrected. Any corrections on exam scores must be made before the next exam, or two weeks after the exam was returned, whichever comes second. The only corrections made after this time period will be for simple addition errors in scoring.

10. **Lab Assignments** - Simulation and design lab exercises are conducted in small teams. A single assignment is submitted for each lab group. Collaborations with other groups, including shared diagrams or extensive discussion of results, must be acknowledged at the end of your assignment. Lab assignments are not formal reports. Specific requirements for what to submit are given with each assignment.

11. **Late assignments** will only be accepted under extenuating circumstances or with prior approval by the instructors.

Grading

Grading Philosophy

Assignments and exams are graded to an absolute standard designed to indicate your level of competency in the course material. The final grade indicates your readiness to continue to the next level in the curriculum. The AES faculty have set these standards based on our education, experience, interactions with industry, government laboratories, others in academe, and according to the criteria established by the ABET accreditation board.

The course grade is primarily dependent on **individual** measures of competency, i.e. exams. The other course assignments are designed to enrich the learning experience and to enhance individual performance, not to substitute for sub-standard individual competency. Accordingly, group assignment grades are only incorporated into the final grade when the individual grade is a C or better. **In other words, if your individual average is below a C, the group-based grade fraction will not be averaged into your final grade, which will then be based solely on your exam and quiz scores.** This policy makes it important to use the group assignments to enhance *your own* learning. Although it may seem more efficient to split up the assignment among group members, this is dangerous because the learning is also split up, and this often results in poor performance on exams, and significant risk of repeating the course. Recommended practice is to work the assignments first on your own, then use the group interactions and instructor/TA help to answer questions and refine and deepen your understanding.

Grades for the course are set based on the following criteria:

A, A-	Demonstrates mastery of the course material in both conceptual and quantitative aspects.
B+, B	Demonstrates comprehensive understanding of the material, with a solid conceptual grasp of key concepts and strong quantitative work.
B-, C+	Demonstrates good understanding of most key concepts, with few major quantitative errors.

C	Demonstrates adequate understanding of the material to proceed to the next level; sufficient quantitative work.
C-	Does not demonstrate adequate understanding of the material to proceed to the next level, or makes persistent quantitative errors.
D	Very little understanding is evident, consistently poor quantitative work.
F	Unsatisfactory performance.

Grade Breakdown

Your final grade is a combination of an individual work (IW) and group work (GW) score.

Type	**Description**	**Percentage**
Individual Work (IW)	Reading Quizzes	10%
	Exams (3 Exams)	60% (30% Each)
	Final Exam	30%
IW Score	Total Individual Score	100%
Group Work (GW)	Homework*	30%
	Lab Assignments	70%
GW Score	Total Group Score	100%

Final Course Score

Your final course score is computed as follows

- If your Individual Work (IW) grade is **below a C**, then your Final Score (FS) is the Individual Work (IW) score. In this case FS = IW.

- If your Individual Work (IW) grade is **a C or better** then your Final Score is computed as the weighted average of the Individual Work (IW) and Group Work scores (GW). This formula is

  $$FS = 0.6*IW + 0.4*GW,$$

  subject to the limitation that averaging in your GW score does not reduce your FS. Thus the group work score can only help your final grade, often significantly.

  This is then equivalent to an overall breakdown:

Reading Quizzes	6 %
Homework	12 %
3 Exams	36 %

Lab Assignments	28 %
Final Exam	18 %
	100 %

Exam Schedule

Exam 1: Thursday, September 29, in class
Exam 2: Tuesday, November 1, in class
Final Exam: Monday Dec. 12, 4:30 – 7:00 pm, in classroom

Homework and Lab Assignment Schedule

Homework and Lab Assignments will be posted and due on alternating weeks. See the end of this document for the full schedule. Homework must be completed individually. Only one lab assignment is submitted per lab group.

Reading Quiz Schedule

Reading quizzes will be conducted on-line through Canvas. They will be open each week (except when there is an exam) from Wednesday at 5:00 PM until Thursday at 3:00 PM. Only one attempt of each question is allowed, and Quiz answers will not be accepted after the deadline. Solutions will be posted after the deadline.

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 Honor Code may include, but are not limited to: 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 Student Conduct & Conflict Resolution (honor@colorado.edu); 303-492-5550). Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

General University Policies

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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. For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

Requirements for COVID-19

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).

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. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

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.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these policies, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

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.

See the campus policy regarding religious observances for full details.

Schedule

Week	Dates		Tuesaday			Thursday			Lab	(T/W/Th)
1	8/22/-8/26		Nomenclature			Coordinate Frames and Euler Angles (Ch 4.1, 4.4)	Reading Quiz 1			Lab 1 Assigned
2	8/29-9/2	Equations of Motion;	Equations of Motion - Kinematics (Ch 4.4)	HW 1 Due		Equations of Motion - Dynamics (Ch 4.2-4.3, 4.5, 4.7)	Reading Quiz 2			
3	9/5-9/9	Intro to Aircraft Dynamics and Control;	Quadrotors Dynamic			Linearization	Reading Quiz 3		Lab 1 Due	Lab 2 Assigned
4	9/12-9/16	Quadrotor	Quadrotor Modal Solutions	HW 2 Due		Quadrotor Stability and Control				
5	9/19-9/23		Quadrotor Guidance *[Exam 1 to here]*			Longitudinal Forces and Moments			Lab 2 Due	Lab 3 Assigned
6	9/26-9/30		Longitudinal Trim and Stability (Ch 2.1-2.4)	HW 3 Due		**Exam 1**	Reading Quiz 4			
7	10/3-10/7	Fixed-Wing Aircraft:	Longitudinal Stability Derivatives (Ch 5.1-5.5)			Longitudinal Linear Model (Ch 4.9-4.10)	Reading Quiz 5		Lab 3 Due	Lab 4 Assigned
8	10/10-10/14	Longitudinal Stability and	Longitudinal Modes (Ch 6.2)	HW 4 Due		Short Period Approximation (Ch 6.3)				
9	10/17-10/21	Control; Modal Behavior	Longitudinal Control (Ch 7.1-7.7) *[Exam 2 to here]*			Lateral Forces and Moments	Reading Quiz 6		Lab 4 Due	Lab 5 Assigned
10	10/24-10/28		Yaw Stiffness and Dihedral Effect (Ch 5.6-5.9)	HW 5 Due		Coordinated Turn (Ch 3.8-3.13)	Reading Quiz 7			
11	10/31-11/4	Fixed-Wing Aircraft:	**Exam 2**			Lateral State Space Model	Reading Quiz 8		Lab 5 Due	Lab 6 Assigned
12	11/7-11/11	Lateral Stability and Control	Lateral Dynamic Modes (Ch 6.7)	HW 6 Due		Modal Approximations and Control Derivs. (Ch 6.8)				
13	11/14-11/18		Lateral State and Stability Augmentation (Ch 7.8-7.12)			Lateral Stability and Control Augmentation (Ch 8.1-8.9)	Reading Quiz 9		Lab 6 Due	Lab 7 Assigned
14	11/21-11/25	FALL BREAK				FALL BREAK				
15	11/28-12/2		Lateral Transfer Functions	HW 7 Due		Aircraft Transfer Function Matrices	Reading Quiz 10			
16	12/5-12/9		Review			Review			Lab 7 Due	
			NO CLASS							