ASEN 3728
Aircraft Dynamics
Course Syllabus

Lecture: AERO 120   Tues, Thurs   11:30 – 12:45 pm

Instructors

Professor Nisar Ahmed
Office: AERO 265   Phone: (303) 492-0286   Email: nisar.ahmed@colorado.edu
Office Hours: TBA (will announce in lecture and post on Canvas)*

TAs/TFs will be available to assist students and answer questions during regular Aerospace Study Hall Hours: Tues/Thurs 5:30-7 pm, AERO 114, throughout the semester. They will also be available to answer online questions on Piazza and by email.

Any extra office hours for individual TAs/TFs will be announced in class and posted on Canvas.

Text

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

Optional/supplemental resources for your own benefit (not required):
Small Unmanned Aircraft: Theory and Practice, Randal W. Beard and Timothy W. McLain,
            Princeton University Press, 2012.
Flight Stability and Automatic Control, 2nd Ed., Robert C. Nelson, McGraw-Hill, 1998.

Prerequisites

ASEN 2802, 2803, 2804, and APPM 2360.

Overview

This course covers the key ideas that enable: (i) an understanding of how aircraft work and tools for quantitative analysis, and (ii) 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 underlying 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 individually and in assigned groups, consisting of analysis, simulation, and design problems, including development of MATLAB simulation models for two very different vehicles: a quadcopter and a conventional fixed-wing airplane.

In their full expression, aircraft dynamics possess astounding complexity. 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
- Feedback variable selection, control structure
- Effects on mode eigenvalues

Teaching Modalities

Lecture – Lectures will be in person throughout the semester. **All lectures will be automatically recorded and uploaded to the course Canvas page via CU's Classroom Capture system**. "Skeleton notes" will be provided and posted prior to each lecture in the form of partially filled slides, and completed notes will be provided after each lecture. Additional reading and reference materials outside of the main textbook may also be occasionally assigned and posted to the Canvas page throughout the semester.

ASEN 3801 Labs –There is no specially designated lab component for this course. However, content from this class will be reflected in group assignments to be completed in the separate ASEN 3801 Aerospace Dynamics and Controls Laboratory course.

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. As noted above, some supplementary material will also be provided. **The textbook contains a wealth of information, but the concepts and notation are new to most: <u>some sections need to be read more than once to fully grasp the material</u>**!

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. Students are encouraged to "follow along" the lectures by filling in the partial notes on their own – either during class or afterwards

using the lecture recordings. Questions are highly encouraged during lectures, and will be prompted often.

Homework – Homework problems provide individual practice in solving problems of varying difficulty and sometimes will also involve some 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 problem-solving will allow for considerable collaborative learning opportunities.

Reading Quizzes – These will be administered through Canvas on an almost weekly basis alongside homeworks, and will cover the reading material and lectures. **Quiz grades will contribute to your individual course grade and are designed to encourage you to come to class prepared.** They will consist of true-false and multiple-choice-style questions similar in format to questions that will be on the exams.

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

A secondary objective of the Assignments is the development of proficiency with numerical simulation, and to develop good basic programming habits. Simulation is now 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 mid-term exams are planned for week 6 and week 12; **the final exam date and time is Thursday April 30, 10:30 am -12:00 pm.** 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 quarter of the course material. **To help students study and prepare for each exam, equation sheets will be provided to students at least one week prior to the date of the exam (if not sooner)**. Students will be permitted to use scientific calculators for exams.

Logistics

1. Office hours for Instructor will be announced on Canvas and in class. TAs and TFs will be available during Aerospace Study Hall during the semester, and may also announce additional individual office hours. These office hours are intended to provide ease-of-access to Instructor and TA help, primarily during group work on the weekly assignments, but any questions about course material are welcome. This mode of "supervised learning" can be quite efficient, particularly if groups are prepared by attempting the assignments ahead of time and come prepared with questions. Private meetings with instructors or TA/TFs can also be arranged if needed.

2. <u>Email and Piazza questions</u>: Students may email the instructor questions or post questions for the teaching team on Piazza throughout the week regarding course material. DO NOT expect

an immediate response. Any question received by 2 PM should typically receive a response by evening the same day. Questions received after 2 PM may not receive a response until 5PM the next day. Always include "3728" in the subject of any emails related to the class (enables efficient search).

3. <u>Attendance</u> at all lectures is essential. Students who come to class prepared and participate in discussions typically have a more rewarding experience. The instructor will also be available any time after and in between lectures to answer questions – if the office door is open, please just be sure to knock first to see if that is a good time to ask your question!

4. <u>Taking your own notes</u>: 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!

5. <u>Homework</u> - 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 be returned to you without being graded and a score of zero recorded.

6. <u>Reading Quizzes</u> will be given weekly in an on-line format through Canvas. These will cover the reading material, lectures, and may re-emphasize portions of the weekly Assignments. Quiz grades will contribute to your individual course grade. Reading quizzes will be regularly administered through Canvas almost every week, i.e. except when there is an exam. Students will have at least 48 hours to complete each quiz from the time of release (additional time may be allotted depending in circumstances). Solutions to the quizzes will be posted on Canvas once the quiz period is over – use these solutions to help you prepare for future assignments and exams!

7. <u>Examinations & Comprehensive Final</u> – Midterm 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 later**. The only corrections made after this time period will be for simple addition errors in scoring.

8. <u>Deadlines</u> – Deadlines must be enforced to ensure fairness to all students and to enable timely grading. Late assignments are subject to a 20% penalty per day. (E.g. 0-24 hours late = 1 day penalty) except under extenuating circumstances. If such a circumstance occurs you are expected to contact the instructor and TF/TF immediately by email, before the due date. **No other accommodations will be provided, e.g. a hectic schedule or crashed computer will not be considered.** Please plan for these contingencies by including some margin in your schedule. If you know in advance that you will not be on campus for a due date, you may

submit your assignment to the instructor any time prior to the due date. **It is your responsibility to manage assignment submissions and deadlines.**

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 academia, and according to the criteria established by the ABET accreditation board.** As with all other standards that you will encounter throughout your professional, these standards are non-negotiable.

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. **This policy makes it important to use the assignments to enhance your learning.**

Grades for the course are **earned** 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.

In this course, students will be graded on a positive/"value added" system – that is, graders will assess whether responses provided by students reflect knowledge, understanding and reasoning processes that **meaningfully contribute** to answering questions posed on assignments. Empty and "fluff" responses (e.g. repeating questions, verbal/buzzword spaghetti throwing, random diagram drawing, etc.) are easily seen through and will not suffice. **This subject is difficult and non-intuitive, and since this is the first time most (if not all) students have seen this material, it is naturally assumed that all students must work hard and put in effort to learn the concepts.** Therefore, hard work is necessary, but not sufficient by itself, to do well. Your effort must translate to demonstrable individual understanding for success.

Grade Breakdown

Description	Percentage
Homeworks	10%
Reading Quizzes	10%
2 x Midterm exams	50% (25% Each)
Final Exam	30%
Total Score	100%

Note: the lowest homework grade and the lowest quiz score will be dropped from the final course grade calculation.

Exam Schedule

The first two in-class exam dates are subject to possible revision (if needed) during the semester:
Exam 1: Thursday 12 February, 11:00 – 12:45 pm
Exam 2: Thursday 12 March, 11:00 – 12:45 pm
Final Exam: Thursday 30 April, 10:30-12:00 pm

Homework and Quiz Assignment Schedule

Homework and Quizzes will be posted on Canvas. See the end of this document for the anticipated full assignment schedule. Homework and quizzes must be completed individually. Homeworks will be submitted and graded via Gradescope. Reading quizzes will be open each week (except when there is an exam) for at least 48 hours from the initial posting time. Two attempts are provided for each quiz with the highest score recorded. Reading quiz submissions will not be accepted after the deadline.

General Policies

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure 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, marital status, political affiliation, or political philosophy.

Additional classroom behavior information

- [Student Classroom and Course-Related Behavior Policy](#).
- [Student Code of Conduct](#).
- [Office of Institutional Equity and Compliance](#).
- [Student Code of Conduct](#).

- [Office of Institutional Equity and Compliance](#).

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

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.

If you have a temporary illness, injury or required medical isolation for which you require adjustment, **please email the instructor to work out any necessary accommodation**.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have your preferred name (rather than your legal name) and/or your preferred pronouns appear on your instructors' class rosters and in Canvas, visit the [Registrar's website](#) for instructions on how to change your personal information in university systems.

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 (including use of paper writing services or technology [such as essay bots]), 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. Understanding the course's syllabus is a vital part of adhering to the Honor Code.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from Student Conduct & Conflict Resolution and will be subject to academic sanctions from the faculty member. Visit [Honor Code](#) for more information on the academic integrity policy.

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 [protected-class](#) discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-

campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email OIEC@colorado.edu. Information about university policies, reporting options, and OIEC support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors are required to inform OIEC when they are made aware of incidents related to these concerns regardless of when or where something occurred. This is to ensure the person impacted receives outreach from OIEC about resolution options and support resources. To learn more about reporting and support a variety of concerns, visit the Don't Ignore It page.

Religious Holidays

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments, or required attendance. Please communicate the need for a religious accommodation in a timely manner.

In this class, **please email the Instructor <u>at least two weeks in advance</u> to work out any necessary accommodation. Last-minute/day-of-assignment requests are often very challenging to oblige, so adequate lead-time is needed by the teaching team to ensure that fair and reasonable accommodation can be provided in a timely manner.**

Mental Health and Wellness

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS), located in C4C, or call (303) 492-2277, 24/7.

Acceptable Use of AI-based Tools in This Class

Generative artificial intelligence tools, i.e., software that reproduces text, images, computer code, audio, video, and other content, have become widely available. Well-known examples include ChatGPT for text and DALL•E for images. This statement governs all such tools, including those released during our semester together. Keep in mind that the goal of gen AI tools is to reproduce content that seems to have been produced by a human, not to produce accurate or reliable content; therefore, relying on a gen AI tool may result in your submission of inaccurate content. It is your responsibility, not the tool's, to assure the quality, integrity, and accuracy of work you submit in any college course.

If gen AI tool usage is suspected in completing assignments for this course in ways not explicitly authorized, the Instructor will follow up with you. The Office of Student Conduct & Conflict Resolution may be contacted to report suspected Honor Code violations. In addition, you must be wary of unintentional plagiarism or data fabrication. Please act with integrity, for the sake of both your personal character and your academic record.

In this course, you may **NOT** use gen AI tools to produce any results that you are required to report on any assignments (quizzes, homeworks, exams) - this includes code generation for assignments that involve any form of computer programming. Outside of these assignments, you are free to experiment with and leverage gen AI tools to help you explore and better understand the course material, keeping in mind the ethical and information accuracy/integrity issues mentioned above.

Anticipated Class Schedule

The expected course schedule is as follows, with book chapter readings from Etkin and Reid indicated in parentheses. Some updates and adjustments may occur during course of the semester (any such changes will be announced in class and on Canvas):

No.	Dates	Unit	Tuesday	Thursday	Quiz	HW Out	HW Due
1	1/06-1/08	**Equations of Motion; Intro to Aircraft Dynamics and Control: Quadrotor Example**	--no classes--	Introduction; Vectors Review and Nomenclature (Ch. 1.1,1.2,1.3,1.6)	Quiz 1	--	--
2	1/13-1/15		Coordinate Frames and Euler Angles	Equations of Motion – Kinematics (Ch. 4.1, 4.4)	Quiz 2	HW 1 out	--
3	1/20-1/22		Equations of Motion – Dynamics (Ch. 4.2-4.3,4.5,4.7)	Quadcopter Dynamics	Quiz 3	HW 2 out	HW 1 due
4	1/27-1/29		Linearization	Quadcopter State Space Models	Quiz 4	HW 3 out	HW 2 due
5	2/03-2/05		Quadcopter Stability and Control	Quadcopter Guidance	Quiz 5	--	HW 3 due
6	2/10-2/12		Review for Exam 1	**Exam 1 (in class)**	-	--	--
7	2/17-2/19	**Fixed-Wing Aircraft: Longitudinal Stability and Control**	Longitudinal Forces/Moments	Longitudinal Trim and Stability (Ch. 2.1-2.4)	Quiz 6	HW 4 out	--
8	2/24-2/26		Longitudinal Stability Derivatives	**Midsemester Reading Day (no classes)**	Quiz 7 (Fri)	HW 5 out (Fri)	HW 4 due (Fri)
9	3/03-3/05		Longitudinal Linear Model (Ch. 4.9-4.10); Longitudinal Modes (Ch. 6.2); Modal Approximations (Ch. 6.3)	Longitudinal Control (Ch. 7.1-7.7)	Quiz 8	--	HW 5 due
10	3/10-3/12		Review for Exam 2	**Exam 2 (in class)**	-	--	--
11	3/17-3/19	SPRING BREAK	NO CLASSES	NO CLASSES			
12	3/24-3/26	**Fixed-Wing Aircraft: Lateral Stability and Control**	Lateral Forces and Moments;	Lateral Stability Derivatives; Yaw Stiffness (Ch. 3.8-3.9; Ch. 4.11);)	Quiz 9	HW 6 out	
13	3/31-4/02		Dihedral Effect (Ch. 3.11-3.12); Lateral Damping Derivatives	Lateral Cross Coupling and Side Forces (Ch. 5.6-5.8)	-	HW 7 out	HW 6 due
14	4/07-4/09		Lateral Linear Model (Ch.4.7-4.10)	Lateral Dynamic Modes (Ch. 6.7)	Quiz 10	HW 8 out	HW 7 due
15	4/14-4/16		Lateral Modal Approximations; Lateral Control Derivatives	State and Stability Augmentation (Ch. 6.8)		--	HW 8 due
16	4/21-4/23	**Fixed-Wing Aircraft: Stability and Control of Complete Aircraft**	Aircraft Handling Qualities and Control Design Criteria; Aircraft Guidance Strategies	Last Class: Final Review (students come with questions; no slides except to work example problems)		--	--
	4/30	**FINAL EXAM: Thursday April 30, 2026 – 10:30-12:00 pm**					