ASEN 6519: SPACE VEHICLE GUIDANCE AND CONTROL
FALL 2018

Instructor: Jay McMahon, Office: ECNT 416, email: jay.mcmahon@colorado.edu

Lectures: MW 3:00 - 4:15, ECCR 150

Course Web Site: Canvas (https://canvas.colorado.edu)

Office Hours: TBD

Final Exam Period: Tuesday, December 18, 7:30 - 10:00 PM

Text: "Required" text: Kabamba, P. T., and Girard, A. R., *Fundamentals of Aerospace Navigation and Guidance*, Cambridge, 2014

References: There are a number of books that are good references on a variety of subjects covered in this course:

- Stengel, R. F., *Optimal Control and Estimation*, Dover, 1994
- Lawden, D. F., *Analytical Methods of Optimization*, Dover, 2003
- Lawden, D. F., *Optimal Trajectories for Space Navigation*, Butterworths, 1963
- Kirk, D. E.,*Optimal Control Theory*, Prentice-Hall, 1970
- Zarchan, P., *Tactical and Strategic Missile Guidance*, Fourth Edition, Progress in Astronautics and Aeronautics, 2002
- Noton, M, *Spacecraft Navigation and Guidance*, Advances in Industrial Control, Springer, 1998
- Battin, R. H., *An Introduction to the Mathematics and Methods of Astrodynamics, Revised Edition*, AIAA Education Series, 1999
- Battin, R. H., *Astronautical Guidance*, McGraw-Hill, 1964
- Bryson, A. E., and Ho, Y. C., *Applied Optimal Contro*, Taylor & Francis, 1975
- Ben-Asher, J. Z., *Optimal Control Theory with Aerospace Applications*, AIAA Education Series, 2010
- Longuski, J. M., Guzmán, J. J., and Prussing, J. E., *Optimal Control with Aerospace Applications*, Springer, 2014
- Wie, B., *Space Vehicle Guidance, Controls, and Astrodynamics*, AIAA, 2015

Goal: To introduce the concept of guidance, derive commonly used guidance laws for aerospace vehicles, and learn how to analyze the performance of guidance systems.

Overview: The course gives a comprehensive view of guidance systems used in space vehicles, and methods for analyzing the performance of these systems. The types of guidance systems that will be covered are launch vehicle ascent, intercept/rendezvous, interplanetary, orbit station-keeping, atmospheric re-entry, lander, and low-thrust. The mathematical foundation of these systems will be derived and discussed. Real world applications will be presented by reviewing selections from published literature. Course work will emphasize the analysis of the guidance system performance to achieve stated goals.

Grading: I use the standard 100 point system for grading. I reserve the right to define the final numeric ranges for each letter grade, although they typically match the standard scale (and won't be higher than) where an A is 90-100, a B is 80-89, etc. I will assign ±'s to the letter grades at the end of the course as I find appropriate. The grade breakdown for this course is:
Homework - 40%
Midterm - 20%
Project - 40%

Homework Policy: There will be 4 or 5 homework sets in this course. At least 2 weeks will be given for each set to be completed. Homework sets will generally involve simulations to be created. Any programming language can be used to create these programs. All assignments, including any code written, will be submitted through the course web site.
There may also be some journal papers assigned as pre-class readings so we can discuss the papers in class. These papers will be posted on the course web page or will be available through the library.

Exams: There will be a take-home midterm exam and no final exam. If you have exam grading issues, you must see me within 2 weeks of having the exam returned to you. See policies below for issues with schedule, although given the take-home nature I don't think there will be issues.

Project: There will be one **significant** semester project for the course. This project will involve more detailed simulation and analysis than a typical homework assignment. The details will be discussed during the semester. A professionally formatted technical report will be required for the project, and there will be a presentation of results to the class at the end of the semester.

Web Page: This semester we will be using Canvas, CU Boulder's new learning management system. We will be using Canvas for posting all class information (assignments, notes, slides); work will also be turned in and returned through this site. There will also be a discussion board that will be used.
To access Canvas, go to: `https://canvas.colorado.edu`. Log-in using your CU login name and IdentiKey password.
Once you log-in, click on ASEN6519 to go into our course.
Make the most out of Canvas by downloading the Canvas Student App to view your grades, view course materials, submit assignments, take quizzes, and more.
Subscribing to notifications to be reminded of due dates, receive announcements, and grades. Browsing the Canvas Guides or help videos for information on how to use Canvas. If you run into any problems, click the Help Icon within Canvas to report a problem or chat 24x7 with Canvas Support.
For additional assistance, contact the IT Service Center at help@colorado.edu or 303-735-4357.

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 policy may include: 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 the Honor Code (honor@colorado.edu); 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Accommodations 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 or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

Classroom Behavior: Students and faculty each have responsibility for maintaining an appropriate learning environment. 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. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

Religious Observances: 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. In this class, I will attempt to accommodate any conflicts with exam times if you let me know at least 2 weeks in advance.
See the campus policy regarding religious observances for full details.

Sexual Misconduct, Discrimination, Harassment And/Or Related Retaliation: The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.
Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Planned List of Topics

(subject to change at the whim of Prof. McMahon)

- **Introduction of the GNC System** [1 class]
- **Review** [2-3 classes]
  - Dynamics, linear control theory, Kalman filtering
- **Introduction to Stochastic Systems** [1-2 classes]
- **Performance Analysis Methods** [1 class]
  - Monte-Carlo simulations, sensitivity analysis, method of adjoints
- **Optimal Control Theory** [4 classes]
  - Derivation of linear quadratic control and Hamiltonian optimal control from a calculus of variations perspective.
- **Missile Guidance** [4 classes]
  - Proportional navigation and Lambert guidance. Applications to rendezvous and intercept problems
- **Launch Vehicle Ascent Guidance** [4 classes]
  - Optimal and near-optimal solutions. Applications: Space shuttle, Apollo, IUS, current launch vehicles
- **Interplanetary Guidance** [2-3 classes]
  - Mid-course corrections and deep-space navigation. Applications: Moon, Mars and any interplanetary missions
- **Station-keeping** [2 classes]
  - Satellite guidance systems for orbit maintenance and maneuvers
- **Atmospheric Guidance** [2-3 classes]
  - Bank-angle control for guided reentry. Applications: space shuttle re-entry, Mars landing, Orion re-entry targeting.
  - First stage launch vehicle control
- **Powered Landing Guidance** [2-3 classes]
  - Final approach guidance and targeting for landing vehicles. Applications: OSIRIS-REx, Mars landers, Apollo.
- **Low-thrust vehicle Guidance** [2 classes]
  - Guidance considerations for low-thrust systems using electric propulsion or solar sails