ASEN 6008 Interplanetary Mission Design

Lectures: Monday 6:00 - 7:15, SEEC 125
Lab: Wednesday 6:00 - 7:15 AERO N125
Office Hours: Wednesday 5:00 p.m. (Zoom initially, transition to campus)
Zoom, by appointment for Distance Students.

Interplanetary Mission Design covers many topics in the field of astrodynamics that are useful when constructing conventional interplanetary mission designs. The course focuses on simple ballistic mission designs, such as the interplanetary trajectories of Galileo, Cassini, New Horizons, and the various missions to Venus and Mars. Other types of interplanetary missions will also be briefly explored, such as SOHO's libration point trajectory design. Students will learn techniques to design interplanetary trajectories theoretically using simplified models and to take these theoretical trajectories and transition them into more robust trajectories in the ephemeris. Students will also gain experience using mission design software.

Logistics for Fall 2020 Hybrid Course Modalities/COVID-19–
While campus is in the remote learning mode, lectures will be conducted remotely at the scheduled time or, in some cases, pre-recorded, via Zoom. Classroom capture and Zoom recordings will be posted to Canvas. Students enrolled in the on-campus section (ASEN 6008-001) are expected, whenever possible, to attend lecture synchronously and to engage in breakout discussions. Students enrolled in the distance section (ASEN 6008-001B) are encouraged to attend lecture synchronously if your schedule allows. If you cannot attend a lecture synchronously, it is fine to watch the recordings afterwards. Lab sections will meet remotely via Zoom while campus is in remote learning mode. When the campus transitions back to in-person, the labs will be held on campus. Zoom sessions will be run concurrently so that students who wish to participate remotely can do so. In general, the entirety of lab sessions will NOT be recorded. Students in general, but especially when attending class in-person, are expected to follow campus Protect Our Herd practices: https://www.colorado.edu/protect-our-herd.

Pre-requisites:
Courses: ASEN 5050 or equivalent, or the instructor’s consent.
Material: We expect you to know the following (or to learn about these very quickly): Particle dynamics and orbital mechanics, Keplerian orbital elements, Conic orbits.
Access to GMAT software: This can be through a lab on campus, or GMAT can be downloaded to personal computers.

There are no required textbooks for this class. However, these are some suggested texts that are good additions to an astrodynamicist's library:

- **Vallado, *Fundamentals of Astrodynamics and Applications***. We will probably reference this frequently.
- Bate, Roger R., D.D. Mueller, and J.E. White, *Fundamentals of Astrodynamics*, New Dover Publications, New York, 1971.
- Brown, Charles D., *Spacecraft Mission Design*, AIAA Education Series, Reston, VA, 1998.
- Curtis, H., *Orbital Mechanics for Engineering Students*, Elsevier, Butlington, MA., 2005.
- Meeus, J., *Astronomical Algorithms*, Willmann-Bell, Inc., 1991.
- Murray, C.D. and S.F. Dermott, *Solar System Dynamics*, Cambridge University Press, 1999.
- Prussing, J. and B. Conway, *Orbital Mechanics*, Oxford University Press, 1993.

Computing:
Coding software of choice (MATLAB, C, Python, etc). GMAT software.

Grading:
- Homework: 30%. There are typically 9 assignments in the class.
- Labs: 30%. There are typically 6 labs and 1 midterm project. The midterm project is weighted as 2 labs.
- Final Project: 40%. There are several separate submissions for the final project. Due dates and point values will be clearly denoted on the assignment. The Final Project will be announced in March.
- There are no exams in this class and there are no dropped assignments. If you don't submit an assignment, it is counted as a zero.

Assignment submission
- Collaboration is permitted on assignments. However, each student must submit a **unique** assignment write-up.
- Many assignments in the class will require coding. You may use the coding language or software package of your choice. It is not necessary to include code as part of your submission. Code **may not** be submitted solely as your solution.
- Partial credit will be given based on intermediate steps and explanations provided in the assignment.
- Assignment due dates will be denoted on the Canvas/Gradescope webpages. Students are responsible to ensure that submitted documents are uploaded correctly, readable, and in the correct location. Corrupt files will not be graded.

Late Policy
- 10% deduction per day.
- I'll grant exceptions for good reasons of course! Please notify me IN ADVANCE if you will be turning something in late (Conference, illness, etc)

Topics:

I. Review
   a. History of Interplanetary Missions
   b. The Two-body problem

   c. The N-body problem
   d. Perturbations
   e. Patched conics
   f. Reference frames
   g. Sphere of Influence
   h. Hohmann transfers

II. Lambert’s Problem
   a. Lambert's general theorem
   b. Type I vs Type 2 orbits
   c. Discussion of Geometry of Lambert's problem
   d. Universal Variables Algorithm
   e. Revisit f and g functions
   f. TOF equations for elliptical, parabolic, and hyperbolic transfers
   g. Multi-Revolution solutions (Type 3, Type 4, etc)
   h. Algorithm for multi-rev solutions

III. Ephemeris
   a. Meeus Coefficients
   b. Discussion of JPL Ephemerides

IV. Pork Chop Plots
   a. Construction and Analysis

V. Gravity Assists
   a. History
   b. Vector Diagrams
   c. Leading vs Trailing
   d. Geometry
   e. Computation of parameters (periapsis radius, turn angles, etc)

VI. B-Plane
   a. Motivation
   b. Geometry and axes derivation
   c. Computing nominal B-Plane parameters
   d. Targeting desired B-Plane parameters
   e. Various targeting algorithms

VII. Resonant Orbits
   a. History (Galileo)
   b. Motivation
   c. Construction

VIII. Mission Development
   a. Using tools to construct end-to-end mission
   b. How to develop an initial itinerary?

IX. Introduction to Trajectory Optimization
   a. How to define an optimal trajectory?
   b. Optimization Problem Setup
   c. Performance index, constraints
   d. Defining state vector
   e. Pruning the search space
   f. Algorithms for optimization

            i. Deterministic vs Stochastic
        g. Examples of optimization algorithms

X. Tisserand Plots

XI. Three Body Problem
   a. History
   b. Simplified forms (Restricted, Elliptical Restricted, Circular Restricted)

XII. Circular Restricted Three Body Problem
   a. Geometry of nondimensional, rotating frame
   b. Derivation of Equations of Motion
   c. Transformation from synodic to inertial frame
   d. Libration Points

XIII. State Transition Matrix
   a. Motivation
   b. Derivation for CRTBP

XIV. Libration Point Orbits
   a. History in Mission Design
   b. Types of orbits (Halo, Lissajous, etc)
   c. Construction of LPOs using Single Shooting Algorithm
   d. Stability

XV. Invariant Manifolds
   a. Definition
   b. Stable/Unstable Eigenvalues and vectors
   c. Computing Invariant Manifolds (general discussion)
   d. Applications to Mission design

XVI. Differential Correction

Additional information regarding general CU classroom policies:

Accommodation for Disabilities
If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries guidelines under the Quick Links at the Disability Services website and discuss your needs with your professor.

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. In this class, please provide me with a list of potential conflicts within the first two weeks of the semester.
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 maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

Honor Code
All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at honorcode.colorado.edu.