Syllabus for ASTE589 Solar System Navigation

Field Label

Day	Wednesday
Time	6:40 pm to 9:20 pm
Room	RTH 109
Instructors	Dr. Gerald R. Hintz (Classes 1-4), Dr. Troy Goodson (Classes 5-8), Dr. Rodney L. Anderson (Classes 9-13)
Office	OHE 500S
Office hours	5:20 pm – 6:20 pm in weeks 2-13
Contact email	ghintz@usc.edu, troy_goodson@iname.com, rlanders@usc.edu

Course Description

Three research and professional engineers will teach a series of advanced topics in Orbital Mechanics. The topics include:

- Free-return circumlunar trajectory analysis,
- The Circular Restricted 3-Body Problem,
- Lagrange points and mission applications,
- Spacecraft targeting encounter and flyby conditions,
- Optimization concepts for trajectories,
- Trajectory optimization methods,
- Dynamical systems theory for mission design,
- Additional 3-body models and the ephemeris model,
- Libration orbit design and continuation,
- Stability and invariant manifolds, and
- The Interplanetary Superhighway and beyond.

Learning Objectives and Outcomes

To learn the topics listed under **Course Description** above.

Prerequisites

ASTE580 or an equivalent course in Orbital Mechanics.

MATLAB or another computer programming language.

Co-requisites

None

Course Notes

Class notes will be provided at least one week before the material will be covered in class.

Required Hardware/Software

None

Required Texts

Gerald R. Hintz, *Orbital Mechanics and Astrodynamics; Techniques and Tools for Space Missions*, Second Edition, Springer, 2022.

J. S. Parker and R. L. Anderson, *Low-Energy Lunar Trajectory Design,* JPL Deep Space Communications and Navigation Series, Volume 12, John Wiley and Sons, Inc. 2014. (Dr. Anderson will supply this reference for free.)
K. E. Davis and R. L. Anderson, *Libration Point Orbiters and the Three-Body Problem,* Encyclopedia of Aerospace

Engineering, Volume 5, 2010. (Dr. Anderson will supply this reference for free.)

Optional Materials

None

Description and Assessment of Assignments

10 homework assignments and 3 take-home exams will be provided one week before they are due.

Generative AI Policy

N/A

Grading Breakdown

Homework total 40%

Take home exams total 60%

Weekly Schedule

Segment 1	Classes taught by Dr. Hintz
Weeks 1-2:	Free-Return Lunar Trajectory Analyses: Parametric plots and application to the Apollo 13 mission ("Houston, we have a problem.")
Weeks 3-4:	Circular Restricted 3-Body Problem (CRTBP), Lagrange points, space mission applications – past, present and future.
Segment 2	Classes taught by Dr. Goodson
Week 5:	Targeting Encounter and Flyby Conditions, including orbital-element targeting, singularities, Russian visual-plane targeting, and Monte-Carlo mission simulation.
Week 6:	Optimization Concepts for Trajectories, including cost functions, local versus global optimization, direct versus indirect, low thrust versus impulsive, scaling the problem, linearization.
Week 7:	Trajectory Optimization – Lagrange multipliers, first variation, two-point boundary value problems, Lawden's primer vector, Multiple-point shooting versus simple shooting.
Week 8:	Trajectory Optimization – Direct Methods, including colocation, direct transcription, nonlinear programming, and the relationship between direct and indirect methods.
Segment 3	Classes taught by Dr. Anderson
Week 9:	Introduction to Dynamical Systems Theory and the Interplanetary Superhighway: Overview of libration point missions, fundamentals of chaotic systems, introduction to multi-body models
Week 10:	Stability in dynamical systems, time and coordinate frames, the general three-body problem, fundamentals of the Circular Restricted Three-Body Problem (CRTBP)
Week 11:	Characteristics of the CRTBP including Lagrange points, the Jacobi constant, Tisserand's criterion, and symmetry
Week 12:	Lagrangian and Hamiltonian CRTBP formulations, introduction to stability in the CRTBP, Lyapunov and halo orbits, and the libration orbit design around the Lagrange points
Week 13:	Periodic orbit families, continuation, the variational equations, and general orbital stability. Overview of other topics: Transfer design using invariant manifolds, heteroclinic and homoclinic connections, low-energy exploration in the Earth- Moon system, and petite grand tours of Jupiter's icy moons

*** The final take home exam for segment 1 will be due in the class for week 5. The final take home exam for segment 2 will be due in the class for week 9. The final take home exam for segment 3 will be due on the Wednesday of week 14.

Value 1

Lectures: Wednesday's from 6:40 pm to 9:20 pm in RTH 109

Labs: None

Lecturers: Dr. Gerald R. Hintz (Classes 1-4), Dr. Troy Goodson (Classes 5-8), Dr. Rodney Anderson (Classes 9-13)

Email addresses: ghintz@usc.edu, troy_goodson@iname.com, rlanders@usc.edu

This course is usually taken by Astronautical Engineering majors after they have taken ASTE580.

Be able to write computer programs in MATLAB or another programming language.

There will be no in-class exams.

Homework

Homework will be assigned in classes 1, 2, 3, 5, 6, 7, 9, 10, 11, and 12, and due Wednesday of the next week.

Take-home tests will be assigned in classes 4, 8, and 13, and will be due the Wednesday of the next week.

Topics

See list of **Course Descriptions.**

Help Text or Value 3

Describe the student audience for whom the course is appropriate.

Advanced students who are working on Master’s or PhD degrees.

After taking this course, the student will be able to:

1. Understand how we returned the Apollo 13 astronauts to Earth safely after an explosion occurred onboard the spacecraft,
2. Compute trajectories in multi-body systems,
3. Compute periodic orbits in the circular restricted three-body problem,
4. Determine the stability of periodic orbits in the circular restricted three-body problem,
5. Identify and describe targeting parameters for hyperbolic flyby,
6. Describe, maybe formulate, a simple trajectory optimization problem,
7. Discuss the relative merits of indirect and direct optimization methods,
8. Distinguish between local and global optimization methods, and
9. Do spacecraft mission design using the Interplanetary Superhighway and beyond.