

Jet Propulsion Laboratory (JPL)

Proposed Summer Student Project

for the Research in Industrial Problems for Students (RIPS) program
of the Institute of Pure and Applied Mathematics (IPAM)

This project aims at creating a simple software tool to help in the design of manifold-type transfers in a multi-gravitational orbital environment and represents a continuation of the effort started with last year project.

Project Overview

This project will characterize the set of ballistic trajectories which do not impact over a sufficiently long time span around planet or planetary satellite (secondary, e.g., Mercury, Moon, Galilean moons) as perturbed by a massive central body (primary, e.g., Sun, Earth, Jupiter respectively). The study will be performed in a simplified model such as the planar circular restricted three body problem that captures the dynamics of interest.

This project is sponsored by the Prometheus project at JPL in the low thrust software tool development effort. Numerical investigations have indeed indicated that minimum fuel low thrust transfers in the vicinity of the Galilean moons of Jupiter present significant impact risks. Thus, a better understanding of the trade-offs between lifetime, transfer boundary conditions and fuel consumption would help in the design of robust low thrust trajectories in such environments. This project will contribute to the effort of better understanding of the dynamical underpinnings of such trade-offs and the targeting methods to deal with the associated risks.

Besides the expected improvement in the theoretical understanding of the above problem, a desired end product of this research project is a simple software tool (generated, for example, using Matlab) that generates initial conditions with prescribed ballistic properties (e.g. lifetime, maximum inclination, orbit geometry with respect to the primary). These initial conditions could be used as a target states to input in an optimizer program.

The solution of this problem should build upon the basic theoretical and computational framework developed by last year's RIPS-JPL team on the "sphere problem". While last year's project only considered the fate of a set of trajectories with respect to a single sphere, this year's project would consider the flow of trajectories between two distinct, concentric spheres (the radius of these being a parameter), and would focus on a range of energy where three-body dynamics are significant.

Participants and Roles

The project is to be performed by a team of four students on the premises of IPAM, under the framework of the Research in Industrial Problem for Students (RIPS) program during the 9 weeks period of June 26 to August 26, 2005. Besides the IPAM support, the students shall receive guidance from Larry Bright (industry sponsor) and Benjamin Villac (faculty mentor) from the Jet Propulsion Laboratory.

The industry sponsor will: (1) provide the students with periodic feed-back on the work performed by the students in order to keep it focused on the sponsor's interests; and (2) organize a visit of the students to JPL for presenting their results to the Mission Design Team.

The faculty mentor will provide the necessary background and educational support to help the students achieve the goals set for this project. The faculty mentor will spend a full day each week at IPAM to directly help the students and shall otherwise be available for answering any question by phone or e-mail during the remaining work hours.

Products

The following products, to be handed in electronic form on a set of CD-ROMs, are expected at the outcome of the project:

- Report on the summer project
- Presentation at the end of the project at JPL
- A set of programs (Matlab scripts) and data resulting from the project.

References

The 2004RIPS-JPL project represents the first necessary background for the students. Going in pair with the project report, the conference paper that has been presented at the 2005 AAS/AIAA Spaceflight Mechanics conference should be used:

Carlo von Kirchbach, Huan, Zheng, Jeffrey Aristoff, Jonathan Kavanagh, Benjamin Villac, Martin Lo, "Trajectories leaving a sphere in the restricted three body problem".

For further background, a basic knowledge on dynamical system theory and a basic understanding of spaceflight mechanics can be obtained from the following textbooks and the paper that inspired the proposed method for this project:

S. Wiggins, "Introduction to applied nonlinear dynamical systems and chaos", Springer, New York, 2003.

W.E. Wiesel, "Modern Astrodynamics", Aphelion Press, 2003.

R.W.Easton, J.D. Meiss and S. Carver, "Exit times and transport for symplectic twist maps", Chaos, Vol. 3, No. 2, 1993.