Proposal for the Research in Industrial Projects for Students (RIPS) Program - 2009

(Institute for Pure & Applied Mathematics – IPAM)

Developing and Comparing Lambert Solvers for Trajectory Design Studies and Space Mission Analyses

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Assuring Space Mission Success

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Project Title: Developing and comparing solutions to Lambert's problem

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Project Description: In orbital dynamics, mission and trajectory design studies often involve orbit transfer, rendezvous, and intercept missions. Mission/trajectory designs in the context of orbit transfer are defined as planning a trajectory sequence that will transfer a spacecraft from one orbit to another. Rendezvous missions are special-case orbital transfers and require matching the position and velocity conditions with a targeted object at the end of the transfer sequence. Intercept missions (also a special-case orbital transfer) require matching only the position with an object at the end of the transfer sequence.

Trajectory design techniques allow a skilled investigator to conduct extensive "what if" analyses to determine the effects of auxiliary mission constraints on primary mission objectives. The trajectory designer (or mission planner) identifies optimal trajectories based upon fuel, time, and/or other mission constraints. Applications of trajectory design include space missions related to interplanetary and near-Earth transfer scenarios. At the most basic level, all of these problems reduce to solving for a trajectory that joins two position vectors, using time-of-flight. This problem was first solved by Johann Heinrich Lambert in 1761, and is usually referred to as Lambert's problem. For Lambert's problem, many people have formulated different ways of solving this transcendental two-point boundary value problem. However, the different schemes vary in terms of accuracy, robustness, and computational speed.

This project involves: a) Conducting a literature search to identify at least four promising Lambert algorithms, b) Extend those algorithms, wherever necessary, to include multiple-revolution solutions, c) Implement the algorithms using the C programming language, being careful to mitigate numerical inaccuracies, and d) Compare the algorithms to exact analytical solutions. The final report will include a detailed comparison of the accuracy, robustness, and computational speed of each Lambert solver.

References:

1. Vallado, David A., Fundamentals of Astrodynamics and Applications, McGraw-Hill, 1997;
2. Battin, Richard H., An Introduction to the Mathematics and Methods of Astrodynamics, Revised Edition, American Institute of Aeronautics and Astronautics, Inc., 1999.

Prerequisites:
Required: C programming, numerical analysis;
Desired: familiarity with orbit mechanics.

Keywords: orbit mechanics, Lambert's problem, mission planning, trajectory design

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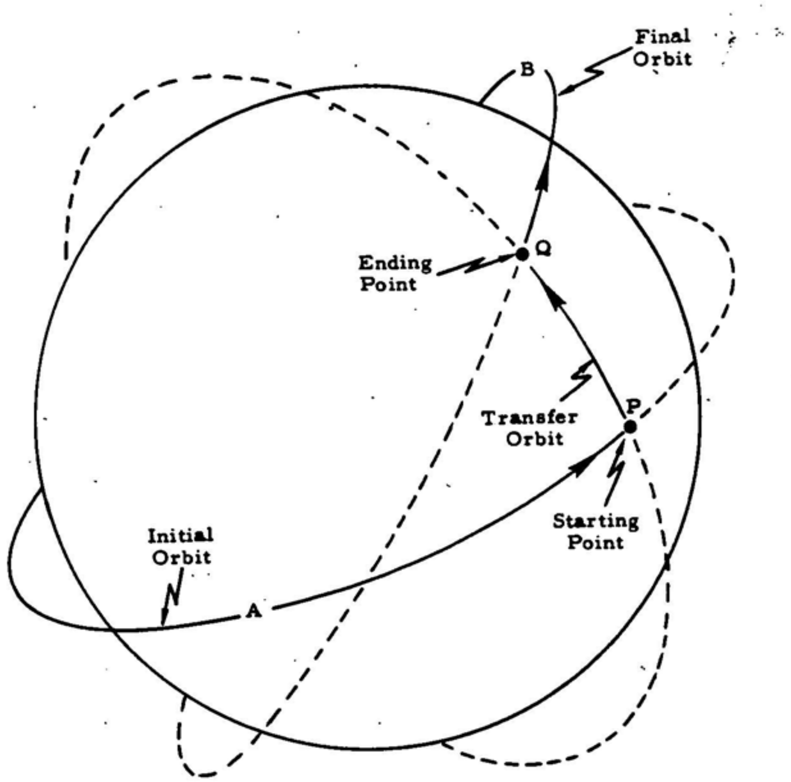

Figure 1. Generic Geometry of Lambert's Problem: Consider two orbits A and B as shown. Assume that we are in Orbit A and wish to transfer to Orbit B. We shall do this by traversing a transfer orbit which starts from point P and ends at point Q. The exact nature of this transfer orbit will depend upon the duration of the flight time we select in traveling from P to Q.