Paper ID: 43948
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (1) (8)

Author: Mr. Robert Pritchett
Purdue University, United States, pritcher@purdue.edu

Mr. Andrew Cox
Purdue University, United States, cox50@purdue.edu
Prof. Kathleen Howell
Purdue University, United States, howell@purdue.edu
Mr. David C. Folta
National Aeronautics and Space Administration (NASA), Goddard Space Flight Center, United States, david.c.folta@nasa.gov
Dr. Daniel Grebow
Jet Propulsion Laboratory - California Institute of Technology, United States, daniel.grebow@jpl.nasa.gov

LOW-THRUST TRAJECTORY DESIGN VIA DIRECT TRANSCRIPTION LEVERAGING STRUCTURES FROM THE LOW-THRUST RESTRICTED PROBLEM

Abstract

One of the primary challenges in the process of low-thrust mission design is the development of an appropriate initial guess for the combined state and control history of a trajectory. To address this challenge, one technique assembles dynamical structures, such as periodic orbits and their associated manifolds into discontinuous chains that are corrected to locally optimal transfer solutions via direct transcription. Typically, the links employed in this orbit chain approach are ballistic trajectories, and thrust arcs are added primarily to facilitate corrections that remove the discontinuities between links. However, employing only natural arcs in an initial guess may obscure the mass or time optimal trajectory which can possess a drastically different geometry and control history after the corrections process. To mitigate this possibility, dynamical structures that leverage low-thrust are incorporated into the orbit chain approach. These additional structures expand the options available for the construction of an initial guess and guide the direct transcription algorithm toward an optimal solution by including an informed approximation of the control history.

In this work a low-thrust (LT) force is added to the equations that define the circular restricted three-body problem (CR3BP) to construct a combined model, the CR3BP-LT. Techniques from dynamical systems theory are applied to gain insight into the combined dynamics and to generate a variety of useful structures. Representative transfer scenarios are employed to demonstrate how these structures facilitate orbit chain construction by offering new geometries and reducing state discontinuities between links. Furthermore, insights from the CR3BP-LT model are employed to inform the selection of arcs included in an orbit chain and to guide the formulation of the initial control history. Following orbit chain assembly, direct transcription is applied to converge upon locally optimal transfer trajectories in the CR3BP. Finally, results are transitioned to a high-fidelity model for validation.

Results indicate that the inclusion of low-thrust dynamical structures within an orbit chain framework is a straightforward and effective approach for low-thrust trajectory design. Moreover, this method is adaptable to a wide variety of system and spacecraft models as well as many different transfer scenarios. This approach is particularly useful for transfer design between stable or nearly stable orbits that do not possess natural manifold structures that facilitate arrival into or departure from the orbits. Overall, low-thrust dynamical structures offer a promising new catalog of options for use in the orbit chain approach

to design optimal low-thrust trajectories.