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Author: Ms. Amanda Knutson
Purdue University, United States, ajknutso@purdue.edu

Prof. Kathleen Howell
Purdue University, United States, *(email is not specified)*

COUPLED ORBIT AND ATTITUDE DYNAMICS FOR A SPACECRAFT COMPRISED OF MULTIPLE BODIES IN EARTH-MOON HALO ORBITS

Abstract

The Circular Restricted Three Body Problem (CR3BP) has been examined extensively in recent years; however, considerably fewer studies incorporate the effects of spacecraft attitude in this regime. Due to the sensitive nature of the dynamics near the libration points, it is of interest to investigate the attitude motion in this vicinity and explore the coupling effects between the orbital motion and orientation in such orbits. A recent investigation examined the motion of a spacecraft constructed as two rigid bodies; the vehicle is located in various planar Lyapunov reference orbits, in the vicinity of the Earth-Moon collinear libration points. The goal of the current investigation is to examine the effects of combining attitude dynamics and nonlinear three dimensional orbits within the context of the CR3BP, to determine the effects that are introduced in halo reference orbits.

A fully coupled orbit and attitude dynamical model is realized using Kane's method, a momentum-based approach. One of the major computational challenges in this process is the management of the disparity in length scales in this problem and a nonlinear variational form is employed to mitigate numerical effects. Generalized speeds are employed to represent the system degrees of freedom. Configuration coordinates, such as Euler parameters, augment the equations of motion to fully describe the behavior of the system. To incorporate the effects of spacecraft attitude into the dynamical model of the CR3BP, the nonlinear variational equations of motion are formulated relative to a known numerical reference path.

The established framework is employed to explore the motion of a spacecraft, defined such that the two rigid bodies are connected by a single degree of freedom joint. To investigate the orbit-attitude coupling, reference trajectories are defined as nonlinear halo orbits near the Earth-Moon collinear libration points. Results are presented for a variety of orbital parameters and spacecraft properties to highlight the effects of the orbit on the attitude motion and the attitude motion on the orbit. Realistic spacecraft dimensions are tested to determine the magnitude of the perturbation caused by the orbit-attitude coupling. Additionally, the model is extended to include other types of perturbations, for example, a spacecraft model for which solar radiation pressure is significant; a potential application that can be introduced is the motion of solar sails. The potential to exploit the natural attitude motion of one or both of the spacecraft bodies for orbit control is also explored.