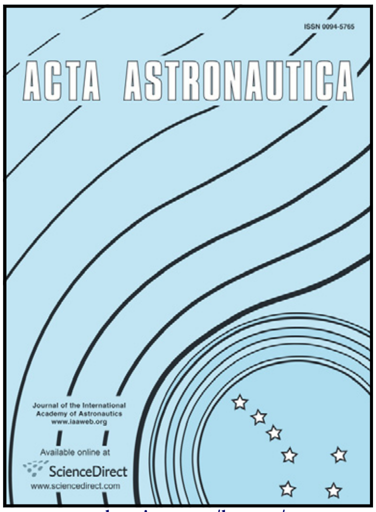
Author's Accepted Manuscript



www.elsevier.com/locate/actaastro

Multiple Spacecraft Formation Reconfiguration using Solar Radiation Pressure

Kamran Shahid, Krishna Dev Kumar

PII: S0094-5765(14)00181-7
DOI: http://dx.doi.org/10.1016/j.actaastro.2014.05.021
Reference: AA5073

To appear in: *Acta Astronautica*

Received date: 6 December 2013
Revised date: 17 March 2014
Accepted date: 18 May 2014

Multiple Spacecraft Formation Reconfiguration using Solar Radiation Pressure

Kamran Shahid* and Krishna Dev Kumar†

Ryerson University, 350 Victoria St., Toronto, Ontario, M5B 2K3, Canada

In this paper the use of solar radiation pressure for spacecraft formation reconfiguration at the L_2 Sun-Earth/Moon collinear libration point is presented. The system consisting of a leader and three follower spacecraft is considered. The leader spacecraft is assumed to be in a fixed halo trajectory and the follower spacecraft position relative to the leader satellite is controlled using two angles and area; these are varied based on a variable structure model reference adaptive control technique to achieve the desired formation reconfiguration. This approach ensures that all follower spacecraft complete the required maneuver in the same time. An intertially fixed circular trajectory, which is suitable for interferometer missions, is used in this paper. The stability of the proposed controller is established using Lyapunov theory. The performance of the proposed controller is tested through numerical simulation of the governing nonlinear equations of motion and is applied for formation initialization, resizing, retargeting, and rotation. The numerical results demonstrate the effectiveness of the proposed control technique for spacecraft formation reconfiguration using solar radiation pressure at the L_2 libration point. Furthermore, control inputs on the order of 15 degrees and 2 m^2 for area change are sufficient to execute the maneuvers.

I. Introduction

Formation flying of multiple spacecraft near the collinear libration points of the Sun/Earth-Moon system offers many possibilities for space exploration. Spacecraft formation flying (SFF) is the concept of distributing the functionality of a single monolithic spacecraft amongst smaller, less expensive cooperative spacecraft. This approach has the potential to enhance space-based imaging interferometry missions by distributing the optical elements of the interferometer over a system of multiple spacecraft flying in precise formation. This allows for longer, adjustable observation baselines, and larger light collecting areas. The Earth orbit environment is unfavorable for precision formation flying due to the high fuel cost required to overcome the local gravity gradient. The Sun/Earth-Moon (SEM) libration points are more suitable locations for precision formation flying missions due to the benign gravity gradient at these positions. There are currently several formation flying interferometry missions under development; these include Darwin,[1] the Stellar Imager,[2] the Terrestrial Planet Finder,[3] and Maxim.[4] These formation flying missions are all designed to be located at the L_2 Sun-Earth/Moon Lagrange point and involve multiple spacecraft flying in precise formation.

Libration points, or Lagrange points, are locations in the orbital plane of two large bodies where the gravitational pull of the two bodies are approximately equal. This allows a third body with relatively small mass to remain stationary relative to the two larger masses. The SEM collinear libration points are well suited for interferometery formation missions since spacecraft near these points have an almost unobstructed view of celestial objects and are not affected by Earth geomagnetic and atmospheric forces. The L_2 point has the additional advantage that the Sun, Earth, and Moon all lie in the same direction thereby reducing the interference from these bodies. The practical development of a libration point formation mission requires a

*Graduate Student, Department of Aerospace Engineering; kshahid@ryerson.ca.

†Professor and Canada Research Chair in Space Systems, Department of Aerospace Engineering; kdkumar@ryerson.ca.