Paper ID: 31746
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ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations (IP)

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FORMATION RECONFIGURATION OF REFLECTIVITY MODULATED SOLAR SAILS AROUND SUN-EARTH LIBRATION POINT

Abstract

Solar sailing has been identified as a promising form of advanced spacecraft for space missions. A solar sail exploits the solar radiation pressure due to the solar photons impinging on a large, highly reflecting surface (the sail) to generate thrust. Recently two solar sail missions, JAXA's IKAROS and NASA's NanoSail-D2, have been successfully launched. More missions, including Gossamer, Sunjammer, and LightSail-A, are under consideration.

In the IKAROS mission, a novel attitude control technique was successfully tested. The spinning of the sail film was implemented using centrifugal forces without the support of any rigid structure. A specific equipment called reflectivity control device (RCD) was utilized to control the attitude of the sail. The RCD is a flexible multi-layered sheet with liquid crystal encapsulated in it. The sheet can switch between specular reflection and diffuse reflection when applying an electrical voltage. This electrochromic technique, referred to as "reflectivity modulation", has great potential for future solar sail missions.

In this work we extend the use of the reflectivity modulation technique to solar sail orbit control. Its application in multiple solar sails formation flying is investigated. Since a high-performance solar sail requires a large-area film with a small payload, the complexity of a single-solar-sail mission is usually limited. In contrast, formation of multiple solar sails is able to perform more complex tasks such as space-based imaging/interferometry missions. Additionally, a formation is reconfigurable to fulfill new tasks and requirements.

This paper discusses the control of formation flying and reconfiguration of reflectivity modulated solar sails around the sun-Earth L_1 libration point. A leader/follower formation scheme is considered. The leader sail is assumed to be in a fixed halo orbit and the position of the follower relative to the leader is controlled using the pitch angle, yaw angle, and reflectivity rate of the sail film. Two different formation configurations, circular configuration and elliptical configuration, are considered. The control law is designed based on an active disturbance rejection control method. The performance of the proposed formation control strategy for reflectivity modulated solar sails is numerically demonstrated.