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WRITING WITH SUNLIGHT: CUBESAT FORMATION CONTROL USING AERODYNAMIC FORCES

Abstract

Small satellite formation missions have long been considered for various important applications where a large number of satellites serve as distributed instruments for atmospheric sampling, construct a distributed antenna platform, make a distributed aperture for imaging, etc. We study the design and evolution through time of small satellite formations comprising a number of spacecraft equipped with drag sails, that can be employed as sunlight reflectors. In the appropriate lighting conditions such formations, given the right attitude of the sails' reflecting surfaces, can be visible from Earth and provide graphic images in the sky. The formations can thus function as space media broadcasting logos or messages.

Preliminary feasibility studies showed that such formations can be deployed using 12U CubeSats with 2x2m2 sails under suitable lighting conditions in a Sun-synchronous orbit. The minimum distance between two reflectors should be greater than 600m to be discernible by the human eye. If the attitude of the image is fixed in the orbital reference frame, it requires continuous control by onboard thrusters and leads to excessive fuel consumption. Another approach is to have the image rotating in the orbital reference frame with an orbital period. Each satellite can be appointed such initial conditions that it moves along a circumference in the orbital reference frame, so each "pixel" in the image rotates with the same angular velocity without control according to the orbital dynamics. However, the control is required to achieve the relative trajectories.

The paper studies the possibility of achieving a defined image configuration of the formation by decentralized aerodynamic-based control. Each satellite is assumed to be equipped with an attitude control system. It allows changing the cross-section area and the attitude of the reflector relative to the incoming airflow, so the differential drag and lift forces appear. The satellites have an onboard navigation system and exchange information on the relative motion via an inter-satellite communication link. The required attitude is calculated for each satellite according to the difference between the actual and required relative motion. The final attitude of the reflectors and the attitude of the image satisfies the observability requirements.