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TOWARDS 100-METRE CLASS MONOLITHIC SPACE STRUCTURES: METHODS TO ENSURE SAIL FLATNESS FOR EXTREMELY LARGE SOLAR SAILS

Abstract

Demonstration of solar sailing techniques has gained remarkable traction in the recent years. Since the first IKAROS demonstration mission, the technique is now being independently demonstrated by a number of space agencies and commercial companies with micro-satellites. Through these efforts, the potential of solar sailing is now well proven, and the next step is to explore the feasibility of large-scale interplanetary missions, which require extremely large solar sails, e.g., 70 m spin-stabilised solar sails. Such unprecedented space structures will undoubtedly find other novel applications in a wide range of areas, including solar power satellites, and microwave and RF aperture synthesis.

The missing key towards such capability is the technique to precisely and reliably control the sail shape, to ensure the high degree of sail flatness required to avoid perturbation solar radiation torques. Past demonstrators have ignored sail deformation and relied on traditional propulsive methods to cancel the resulting perturbation. For large sails, such methods quickly become impractical. For example, this work shows that a 70m sail with just 1 degree sag would require 70 kg of propellant per year to maintain the required sun angle, which would completely defeat the purpose of solar sailing.

This work explores the causes of sail deformation, which include tether length and petal size mismatch and warping surface-mount devices. The concept of “circumferential margin” is introduced as a unified metric to quantify these defects. The sail deformation is explored using the Multi-Particle Method (MPM) numerical modelling technique, and from the sail geometry the perturbation torque is calculated. For a successful propellant-free navigation, these torques must be small enough to be fully counteracted by Reflectivity Control Devices (RCDs) demonstrated on IKAROS.

This presentation proposes two novel approaches to minimise perturbation solar radiation torque. First, allowing the length of central tethers to be actuated to maximise sail flatness in orbit. This method will account for temporal variation in petal and tether sizes. Second, replacing the central tether with rigid booms with controllable length and extension angle, to move the centre of solar radiation pressure with respect to the centre of mass. This versatile approach will be able to minimize perturbation torque as well as generate the desired torque for attitude control.

This presentation will analyse the performance of the above two methods, which will pave the way towards 100 m class deployable space structures, enabling future exploration missions, as well as entirely new classes of space missions.