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SHAPE-CHANGING SOLAR SAILS FOR NOVEL MISSION APPLICATIONS

Abstract

Using conventional solar sailing technology, the solar radiation pressure force vector direction and magnitude depend strongly on the sail attitude relative to the Sun, limiting the applicability of solar sails compared to other low-thrust propulsion systems. In order to increase the flexibility of the thrust force generated, and to increase the range of potential mission applications, this paper introduces concepts of shape change and continuously variable optical properties to large gossamer spacecraft.

Merging these concepts leads to the idea of solar sails as multi-functional platforms that can have potential benefits over conventional solar sails by delivering additional key mission functions such as power collection, sensing and communications. For example, the sail may start at Earth escape in a flat configuration heading towards a designated small body, for a science mission. In close proximity to the target body, the sail reconfigures to a parabolic shape, using its membrane as a remote sensing device or as a large-aperture communication antenna, before continuing again in a flat thrust mode.

This paper investigates the dynamics of a flexible sail membrane with a variable surface reflectivity distribution, which can be achieved through the use of electro-chromic coatings. These consist of an electro-active material that changes its surface reflectivity according to an applied electric charge.

The sail membrane is modelled as a single surface framed by a simply supporting rigid boom structure. When changing the reflectivity coefficient across the sail membrane, the forces and torques acting on the sail can be controlled without changing the incidence angle relative to the Sun. In addition, by assigning an appropriate reflectivity function across the sail, the load distribution due to solar radiation pressure can also be manipulated to control the billowing of the membrane. By an appropriate choice of spatial reflectivity across the membrane, specific geometries can be generated, such as a parabolic reflector, thus enabling a multi-functional sail. This novel concept of optical reconfiguration can potentially extend solar sail mission applications and further enable flexible thrust vector control without using moving attitude control devices.