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DYNAMIC MODEL AND SYSTEM DESIGN OF A 1U CUBESAT DRAG SAIL MODULE

Abstract

Nowadays, the large amount of objects in LEO consists of debris, so de-orbiting strategies must be implemented to ensure satellite disposal after its end of life. In LEO atmospheric drag is the dominant force, so drag sails allow faster re-entry, increasing the exposed area. One of the primary issues of such devices is that they largely depend on attitude control. A potential solution is to model the sail as a pyramid, so that it will re-adjust itself, remaining aligned with the relative wind direction. The scope of the work is to analyse this geometry and provide a solution to sail storage in a 1U CubeSat module.

The implemented dynamical model simulates both the CubeSat orbital and attitude motion during de-orbiting, with the aim of proving numerically the stabilization effect of the pyramidal sail. The model takes into account the major environmental disturbances acting on the satellite as atmospheric drag, solar radiation pressure and gravitational effects (Earth oblateness and gravity gradient). In addition, the sail surfaces self-shadowing was analysed, in order to have a more complete description of the drag and SRP effects. The model was used to test several initial conditions in terms of orbital parameters, understanding the limits of the pyramidal sail as passive attitude stabilization device.

The second part of this work is dedicated to the preliminary design of the module containing the folded drag sail. Firstly, the supports maintaining the deployed pyramidal configuration were selected: the inflatable boom solution was preferred since it guarantees an extremely compact configuration, when folded using Miura-Ori pattern. This peculiar origami shows also a good capability of straight deployment, as demonstrated by the implemented kinematic model. The inflation system, which consists in four spherical tanks filled with nitrogen and a zero-leakage solenoid valve, guarantees proper pressure level inside the booms and consequently their rigidization. Secondly, the sail folding technique was laid out: among different possibilities, the double z-folding was preferred as it ensures ease of manufacturing, compactness and opening simplicity. Finally, the design parameters were selected using a genetic algorithm optimization to test several combinations and determine the most suitable to achieve acceptable booms stiffness, disposal performance and building feasibility.