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DESIGN AND ANALYSIS OF A BIO-INSPIRED BOOM FOR THE DEORBITING MECHANISM OF A SMALL SATELLITE

Abstract

The rising population of space debris poses a great challenge to space exploration. With more than 500,000 pieces of debris, the potential danger of collision with functional spacecraft or satellites increases leading to the creation of more debris. The present paper focuses on the design of a passive deorbit mechanism for India's first twin nanosatellite program STUDSAT-2 featuring the launch of twin satellites STUDSAT-2A and STUDSAT-2B to demonstrate In-Orbit Separation, Inter Satellite Communication, and Deorbiting. An aerodynamic drag-induced deorbiting/re-entry is used as a means to cause the satellite to enter into the dense atmospheric region wherein it heats up and disintegrates eventually. Each satellite is 30 x 30 x 15 cm, weighs less than 5 kg, and is placed in a 650 km polar sun-synchronous orbit. The drag augmentation enables STUDSAT-2B to deorbit at an accelerated timeframe. Mission analysis using AGI's STK estimates a decay time of 337 days with the drag sail which is per the timeframe set by the IADC guidelines. The deorbit module consists of a 6 square meter sail tightly packed in a case and is unfurled by long slender booms coiled around a spindle that is driven by a motor. The chosen configuration of the boom is a tape spring, and the sail is of Kapton material. To address the issue with the low stiffness of the boom which causes buckling and large deformations, a modified cross-section geometry of the boom is implemented which is inspired by nature. The midrib of a leaf acts as a strengthening member that runs longitudinally along the leaf blade supports it against winds and is also flexible enough. The same analogy is applied to the tape spring boom (leaf blade) at the center of which is a small thin strip (midrib) of metal is bonded running along its length. This acts as a reinforcement that prevents the collapse of the boom under load. A parametric analysis with and without the reinforcement is made involving cases with loading conditions due to drag force, tension due to the sail on the boom, and solar radiation pressure. Theoretical values of stresses, area moment of inertia, and elastic energy are compared with FEA results which are essential for preliminary design calculations. By incorporating this simple reinforcement to the boom, large and stable deployable structures can be designed with low cost and ease of fabrication.