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Author: Ms. Alexandra Long
School of Aerospace Engineering, Georgia Institute of Technology, United States

Dr. David Spencer
Purdue University, United States

A PASSIVELY STABLE PYRAMID SAIL FOR THE DEORBIT OF SMALL SATELLITE CONSTELLATIONS

Abstract

Several commercial organizations are developing plans to launch thousands of small satellites into Low Earth Orbit at altitudes ranging from 1,000-1,350 km, with the goal of providing global internet service. There is a clear need to deorbit these satellites at the end of their operational lifetime, in order to preserve the utility of high-value orbit regimes. Without a system to accelerate deorbit, the 150 kg-class satellites would take over 100 years to reenter the atmosphere.

A standardized, bolt-on system is being developed to address the deorbit problem for microsatellites. The Passively Stable Pyramid Sail ($[PS]^2$) is a thin-membrane drag sail with the geometry selected to establish aerodynamic stability. The system is capable of deorbiting small satellites from the planned constellation orbit altitudes within 25 years regardless of the operability of the host satellite. A design requirement of the drag device is that it will aerodynamically trim to a maximum drag attitude in the upper atmosphere, in order to accelerate the deorbit timeline. A stability analysis was conducted to evaluate possible geometries, and it was determined that the drag sail should have a square pyramid shape with an apex half-angle of 75°. For a 150 kg satellite at an altitude of 1,100 km, the system is designed to have a base area of 125 m^2, which requires 8 meter long booms. The mass and stowed volume of the device are designed to be consistent with the 6U CubeSat standard.

A 1/8 scale version of the $[PS]^2$ system was selected for launch through the United Launch Alliance STEM CubeSat program. The mission, called the Aerodynamic Deorbit Experiment, will demonstrate the $[PS]^2$ design from a 1U CubeSat platform. The system will have four 1 m long composite booms, and four triangular sail quadrants made of transparent polyethylene-naphthalate film material. In order to create the pyramid shape, each boom will be deployed from its own boom deployer. This paper will provide an overview of the $[PS]^2$ system, describe the design of the deployment system, and discuss the results of prototype testing.