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The Drag Maneuvering Device for the Semi-Passive Three-Axis Attitude Stabilization of Low Earth Orbit Nanosatellites

Sanny R. Omar, Camilo Riano-Rios, and Riccardo Bevilacqua

University of Florida
Advanced Autonomous Multiple Spacecraft Lab
Gainesville, FL US

Abstract

The increase in use of small satellites since their initial development has led to many missions with simple attitude and orbit control requirements. For example, a small Earth-imaging satellite may require keeping one face nadir pointing within 10 degrees while maintaining a slot in a low Earth orbit within ±100 km. However, legacy attitude and orbit control techniques, including reaction wheels and thrusters, can easily cost tens of thousands of dollars and provide more control capability than is needed for such a mission.

This paper introduces a Drag Maneuvering Device (DMD) that could replace such systems on many missions. Consisting of four retractable tape spring booms deployed in a dart configuration, the DMD can actively modulate the drag area of the host satellite for orbital maneuvering and post-mission disposal while providing passive three-axis attitude stability, using aerodynamic and gravity gradient torques. Magnetorquers integrated into the DMD damp attitude oscillations and help ensure that the satellite stabilizes with the correct face nadir pointing. The current study provides an overview of the DMD design and details the results of the attitude and orbit simulations used to characterize the DMD performance and devise a control and operations methodology. Emphasis is placed on the attitude stability properties of the DMD in this work.

1. Introduction

Attitude and orbit control have been important considerations since the early days of space exploration (Roberson, 1979). Traditionally, attitude control has been performed using reaction wheels (Steyn and Hashida, 1999), control moment gyros, and thrusters; and orbit control has been performed using thrusters (Curtis, 2009; Markley and Crassidis, 2014). These legacy attitude and orbit control systems have been complicated and expensive, but they are also highly accurate and capable of rapid response, making them well-suited to large, high-budget satellite missions. Three-axis attitude control systems have been developed for small satellites such as CubeSats in recent years (Heidt et al., 2000; Mason et al., 2016), but these systems can still cost tens of thousands of dollars. Alternative attitude and orbit control methodologies using environmental forces and torques have been proposed (Shrivastava and Modi, 1983), and

Corresponding Author: Sanny Omar – sanny.omar@gmail.com
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