Design and Analysis of a CubeSat

A Major Qualifying Project

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Contents

List of Tables

List of Figures

Abstract

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1 Introduction

1.1 Purpose

The goal of this project is to design and conduct analysis of a CubeSat on an extreme low Earth orbit (eLEO) mission. The satellite will be carrying a mass spectrometer to conduct atmospheric observation. Following deployment from the ISS the satellite will enter a 250 - 600 kilometer orbit and maintain this orbit as long as possible. The overall project is composed of three separate MQP teams, each responsible for a different aspect of the satellite design and analysis. This portion of the overall project focuses on the attitude determination and control, orbital determination and control, and command subsystems of the satellite.

1.2 Project Constraints

There are four major constraints on this project: the orbit profile, the primary propulsion system, the scientific payload, and the satellite form factor. As mentioned in the introduction, the satellite must enter and maintain a 250 - 600 kilometer orbit as long as possible. This is to allow the scientific payload, the miniature Ion Neutral Mass Spectrometer (mini-INMS), to conduct atmospheric analysis in low Earth orbit. A Busek electro-spray thruster has already been selected as the primary propulsion system for this mission profile and cannot be changed. It is expected that the satellite adhere to the CubeSat form factor, although the final size of the satellite is flexible.

1.3 Educational and Social Impacts of CubeSats

TODO

2 Background

2.1 Mission Profile

There are several distinct mission phases that influence the design of the control systems.

2.2 Attitude Determination and Control

The purpose of the attitude determination and control subsystem (ADCS) is to properly position and orient the spacecraft to meet the needs of the mission. The ADCS is responsible for three distinct operations throughout the mission: detumbling, initial attitude determination, and attitude maintenance. Successful operation in all three phases is vital to the overall success of the mission. This is accomplished by combining a variety of sensors and actuators in a closed-loop control system.

2.2.1 Requirements

Each phase of the mission has different requirements. In order to successfully detumble the satellite must correct for the angular spin imparted during deployment. It is expected that such an angular velocity would not have a magnitude greater than ten degrees per second about any axis. Once the satellite has reduced its angular velocity to less than ??? degrees per second, it must determine its orientation with respect to the Earth inertial frame. From this point onwards the satellite must maintain its attitude within plus or minus five degrees. As the orbit dips lower into the atmosphere the effects of drag become significant. Should the angular orientation deviate further than this limit the torques induced by atmospheric drag risk overcoming the strength of the on board actuators, causing the spacecraft to enter an uncontrollable spin. The torque exerted on the spacecraft can be described as a function of atmospheric density ρ, cross sectional area A, velocity V_{rel}, drag coefficient C_D, center of pressure c_p, and center of gravity c_g, as shown in equation 1.

$$\tau_d = \frac{1}{2}\rho A C_D V_{rel}^2 (c_p - c_g) \tag{1}$$

2.2.2 Sensors

2.2.3 Actuators

2.2.4 Control Logic

2.3 Orbital Determination and Control

2.3.1 eLEO Orbit Decay

2.3.2 Component Selection

2.4 Command and Data Handling

2.4.1 Data Handling Needs

2.4.2 Component Selection

3 Analysis

3.1 Detumbling

3.2 Attitude Maintenance

3.3 Power Requirements

4 Results

5 Conclusion

6 References