Abstract

Recently, ASTRA LLC has teamed with the Space Dynamics Laboratory of Utah State University to design a 1.5U CubeSat system for measuring electric fields. Such a system requires 2-axis control and relatively high spin-rates. The spacecraft is called the Double-probe Instrumentation for Measuring Electric-Fields (DIME) SensorSat and is funded by the Air Force Research Laboratory SBIR program. In order to design and test control algorithms and verify requirements, ASTRA has developed a modeling-tool for a CubeSat 2-axis control system. First, a brief overview of the DIME SensorSat and attitude system is provided and the DIME attitude requirements are introduced. Next the operational attitude model is discussed followed by simulation results for the various operational phases of a spin-stabilized CubeSat. Finally, we present some anticipated challenges and related simulations for a spin-stabilized CubeSat.

Introduction

The 2-axis modeling tool presented here takes into account the use of noisy data, non-rigid hardware, realistic software implementation and computer hardware limitations, environmental torques, power system-attitude feedback, as well as a ground-segment operations and control system. The goal of this work is to demonstrate operational scenarios in which a CubeSat spin-stabilizer feasible given the power and hardware constraints. Throughout the paper, the DIME SensorSat is used as a representative design reference mission. The mission requirements and the satellite itself are described in the following two sections.

Double-probe Instrumentation for Measuring Electric-Fields (DIME)

The DIME SensorSat (see Figure below) design incorporates lessons learned from DICE mission operations (Fish et al. Space Sci Rev, 2014). The CubeSat is capable of deploying flexible electric field booms up to a distance of 10 m tip-to-tip. This is accomplished from the volume envelope of a 1.5U CubeSat, or 10x20x30cm. The satellite will measure AC and DC electric fields, together with ion densities, and magnetic fields to characterize the performance of the sensor in different plasma environments. The DIME SensorSat recently underwent a successful CDR and is currently being built at USU with assistance from ASTRA. Since DIME is a risk-reduction mission, we plan to deploy the wire booms to 3 meter (6 meter tip-to-tip) length, which will require pre-deployment spin rates of 1.5Hz. The box below lists the actuators and sensors used on DIME along with their placement and relationship to the spacecraft body frame. Note that the z-axis is the direction of nominal spin. Below that are the DIME mission objectives.

DIME Sat Spinning CubeSat Attitude Requirements

The objective of the DIME ADCS is to spin-up to rates between 1.0 Hz and 1.5 Hz and align to geodetic north. This flows directly from the mission objectives as well as from the boom-deployment simulation. The figure below shows a simulation of 2-body rates during deployment of the long cable booms as well as the spacecraft before and during boom deployment. An initial rate of 1.5 Hz is required for 3 m boom lengths.

The table on the right summarizes the salient requirements for the DIME ADCS system. Note that several requirements are verified by simulation. The model presented here was designed to perform such simulation-based verification.

Ten-Day Simulation: Challenges and Performance Summary

Challenges for 2-axis, magnetic, ADCS operations on a CubeSat lead to complicated questions about performance. These questions can be evaluated using our model:

(A) Does the CubeSat have enough control authority to spin up to 1.5Hz?
(B) Is there sufficient authority and sensor-sampling to align within 10 degrees of geodetic north?
(C) Can the CubeSat power system support ADCS operations even though the angle to the sun may be changing?

Conclusion

Realistic operational modeling of a spinning CubeSat and its ground-segment was presented. This modeling provides mission designers an effective tool for assessing the performance of open-loop control as well as ground and space system interactions. The tool has allowed us to demonstrate the feasibility of a low-cost and robust method of CubeSat attitude control using a 2-axis architecture.

The Operational Attitude Model

The real-time operational modeling of a spinning CubeSat and its ground-segment was presented. This modeling provides mission designers an effective tool for assessing the performance of open-loop control as well as ground and space system interactions. The tool has allowed us to demonstrate the feasibility of a low-cost and robust method of CubeSat attitude control using a 2-axis architecture.