Passive Attitude Control for Low Earth Orbiting Photographer

Jacob Singleton; Undergraduate Researcher

Dr. Jan Sojka, Faculty Mentor

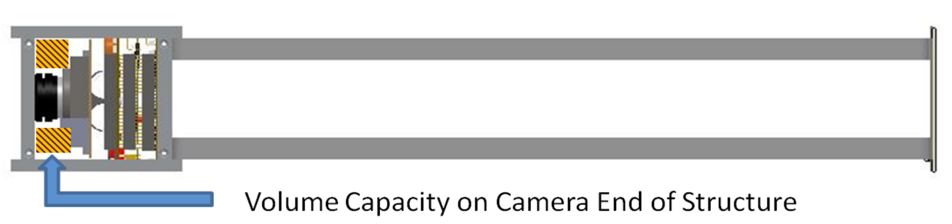
Get Away Special Research Team

Department of Mechanical Engineering, College of Engineering

Background

Low Earth Orbiting Photographer (LEOP) is a 1U Cubesat with a mission to take pictures of the earth and make them available to the public. In order to make this project successful an attitude control system must be developed to gain 3 axis earth-viewing control. Some of the tight constraints unique to Cubesats and LEOP's mission are outlined. The objective is to design a control system that meets the outlined parameters.

- Volume: 10x10x10cm limit for 1U Cubesat
- Mass: 1.3 kg limit for 1U Cubesat
- Power: Limited power with small solar panel surface area
- Budget: Space access designed for university budget
- Complexity: Simplified control system for undergraduates
- Control & Stability: Earth pointing & stable for photo
- Board arrangement & space availability for control system



Volume Capacity on Camera End of Structure

Passive Attitude Control

New technology has made highly accurate active control systems possible with the trade of becoming more expense and greater complexity. We solve three of LEOP's tight constraints by developing a passive attitude control system which uses the earth's gravitational and magnetic fields in the form of a gravity gradient boom, permanent magnets, and hysteresis rods to acquire successful control. This system requires temporary power for a gravity gradient boom deployment and no further active control. In addition to power concerns, it also resolves the concerns with budget and complexity with the system requiring no complex algorithms for expensive active control systems.

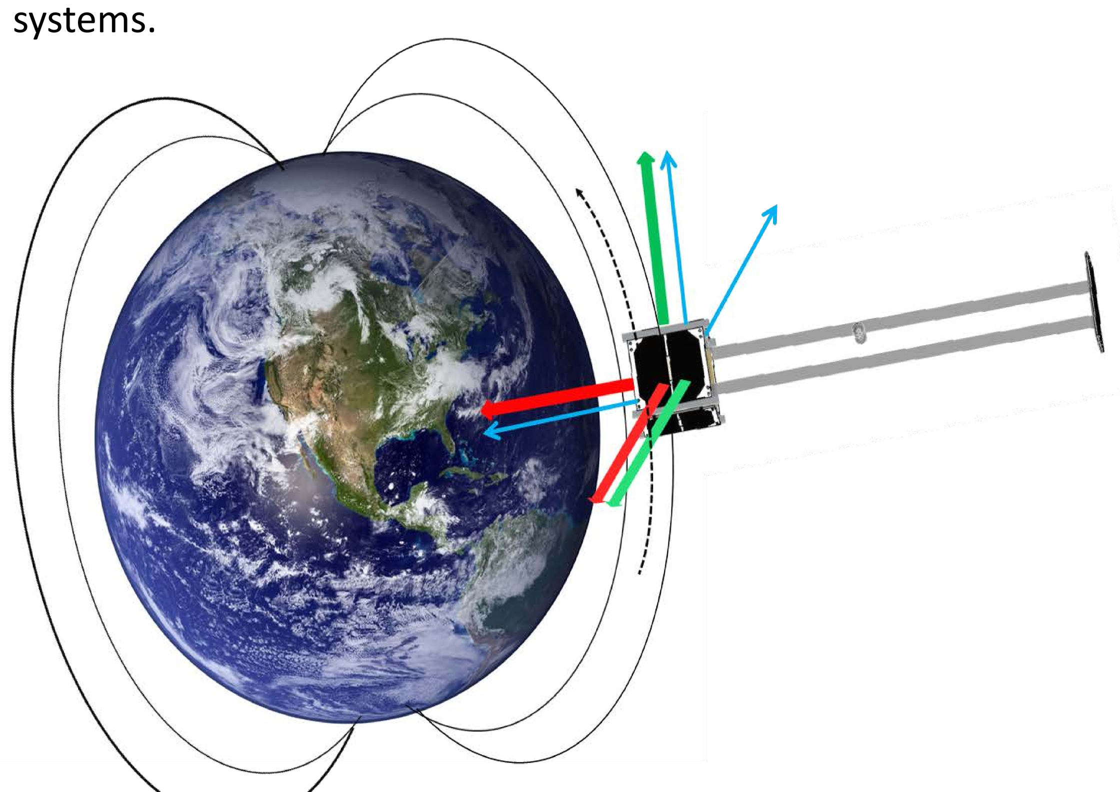
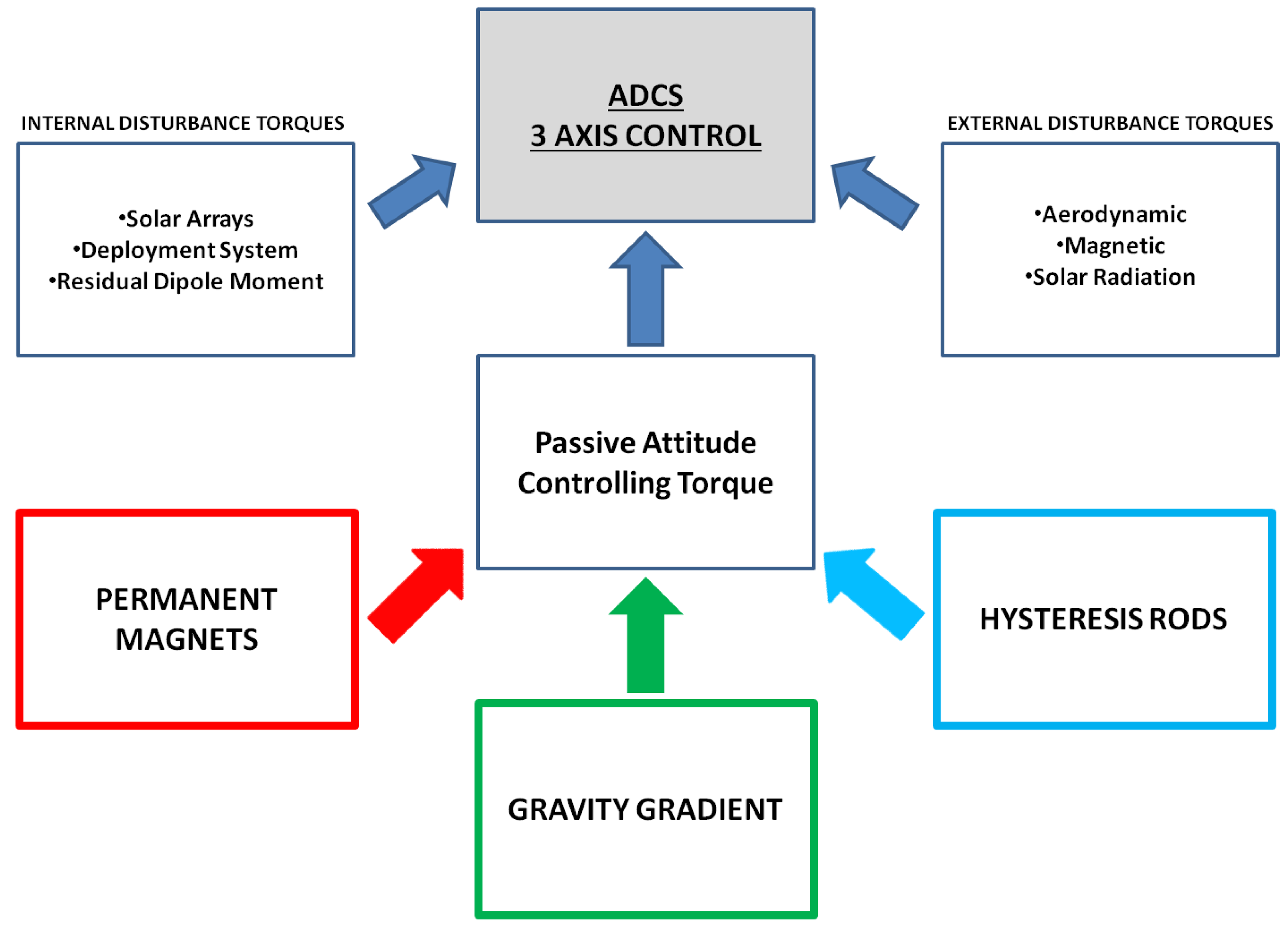


Figure 1- Passive controlling torques represented on LEOP's 3 axis



Gravity Gradient Control

A gravity gradient torque solves the need for earth pointing control and supports the control system in gaining stability with minimal complexity and no sustained power. This controlling torque is created by the difference in the moments of inertia about the z and y axis of the Cubesat. The balance of the gravitational force pulling the satellite towards the earth and the centrifugal force created by the velocity of the satellite drawing it away from earth is what keeps the satellite in orbit. The difference between moments of inertia created by the separated mass causes the spacecraft's major axis to stabilize along the nadir vector pointed towards earth. The three boom deployment actuators researched were spring steel, motors, and a gas actuated balloon.

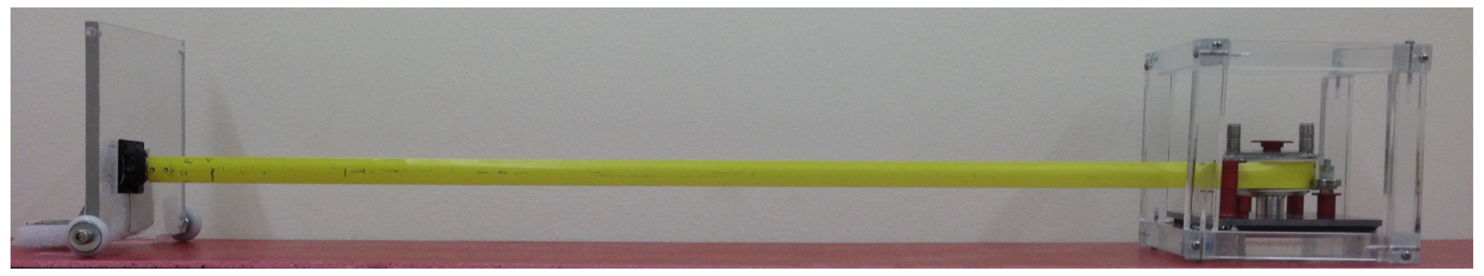


Figure 2- Prototype 1 demonstrating the use of spring steel for .5 meter boom deployment

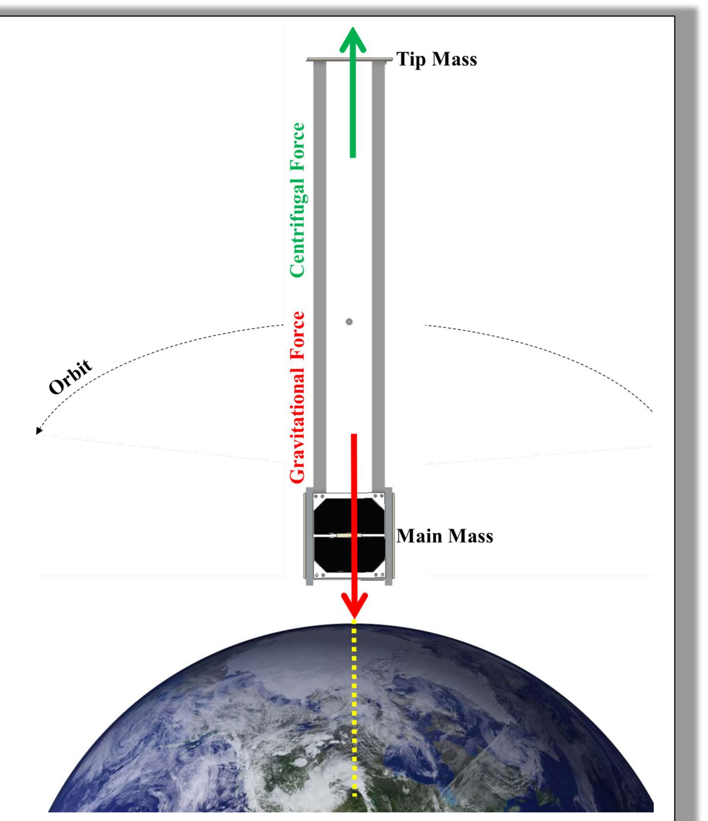


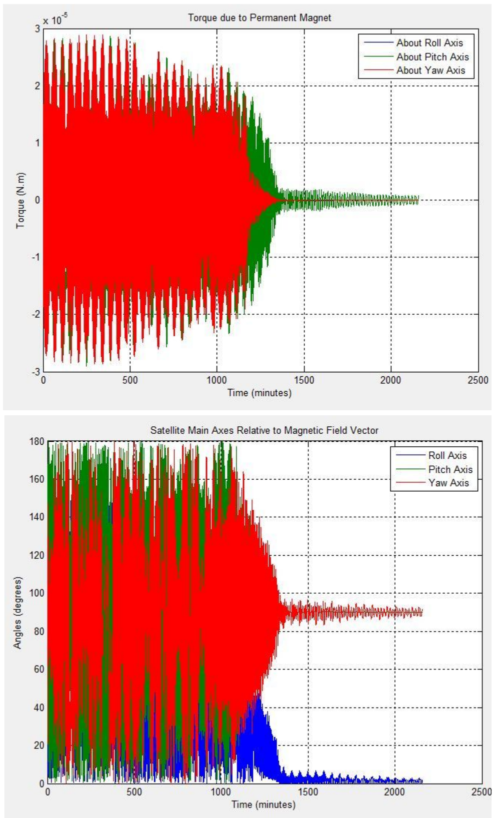
Figure 3- Gravity gradient diagram for LEOP

Impact and Future Work

The contribution of this passive control system will make LEOP possible in meeting the mission's orientation requirements as well as doing so within tight volume, mass, budget, and complexity constraints. Being the first gravity gradient successfully used from a 1U Cubesat platform it will also open avenues for other universities who are seeking to use passive control for science missions that require an earth pointing orientation. Future work will be in studying UV curable epoxies to create rigidity in the boom without further straining the allotted project requirements of mass and volume.

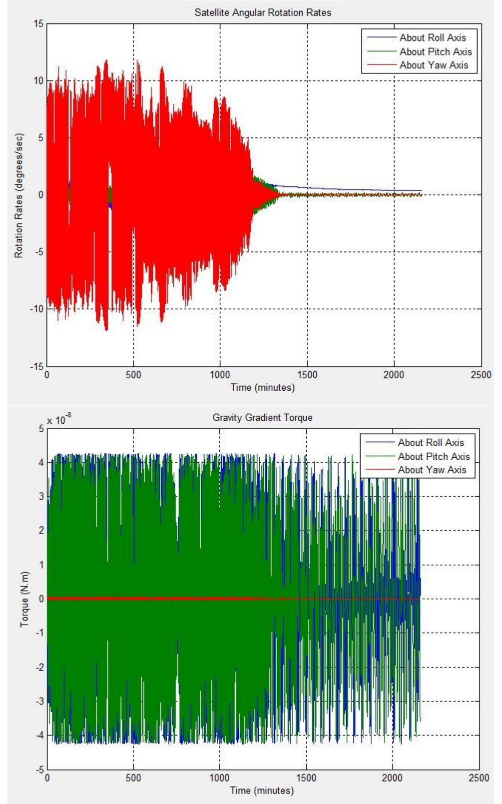
Permanent Magnets & Hysteresis

The earth's magnetic field usually plays a role as a disturbance torque but can be used for passive control. The use of permanent magnets on the roll axis creates a restoring torque to keep it aligned with the earths dipole moment. A torque can be seen on the pitch and yaw axis. The hysteresis material assists stability from dampening motion by shifting polarities with a delayed response to the change in the magnetic field as LEOP orbits. Both elements of passive magnetic control solve concerns with all outlined project constraints except gaining earth viewing control.



Actuators for Boom Deployment

The first considered actuator was coiled spring steel using strained energy in the steel as the actuating power to deploy the tip mass. While this system has heritage in space it was not feasible with the structure arrangement. The only available volume is on the camera end of the Cubesat when the boom needs to be deployed from the opposite end. Second was a motor allowing active control and the benefit of being able to retract a boom. Motors are not reliable and can be expensive with out meeting all of the project constraints.



A gas actuated balloon is chosen to act as the actuating power for the boom deployment. Following the guidelines set by CalPoly, compressed air on board LEOP in the available space will deploy the half meter boom by inflating a balloon. This resolves volume and mass constraints while efficiently using space with the current structural arrangement.

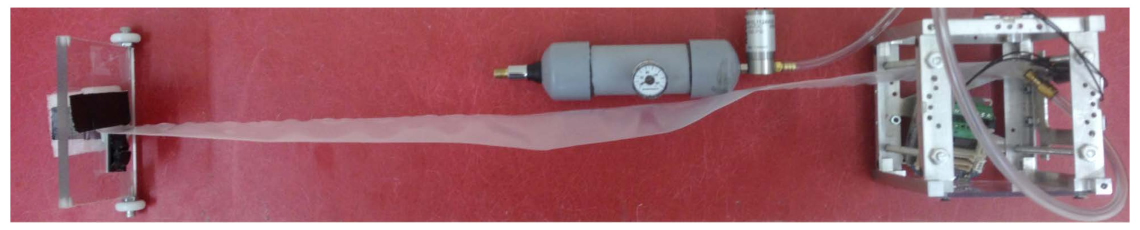


Figure 4- Prototype 1 of gas actuated inflatable boom deployment system

Acknowledgements

Undergraduate Research & Creative Opportunities
USU Get Away Special Team
Dr. Jan Sojka
USU Physics Dept

Jim Elwell
John Elwell
Space Dynamics Laboratory
Reese Fullmer
USU MAE Dept.

USU College of Science
USU College of Engineering
Rocky Mountain NASA Space Grant Consortium
University of Kentucky
Montana State University