Passive Attitude Control for Low Earth Orbitering Photographer

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Background
Low Earth Orbitering 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

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 actuation required. 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.

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 x, y, and z axis of the Cubesat. The balance of the gravitational force pulling the satellite towards the equator 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.

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 roller axis creates a restoring torque to keep it aligned with the earth’s 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.

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.

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