Air bearing test rig for a CubeSat altitude stabilization system

Tyler Peterson, Dmitry Rivkin, Gabriel Elkaim Ph.D.

Abstract

CubeSats are small satellites 10cm on a side that have been introduced to dramatically reduce the cost of space exploration. Typically, they are launched as "secondary" payloads on rockets in orbits and altitudes of convenience (mostly in LEO). Several have been designed and flown by student groups, and CubeSats offer a manageable gateway to space. However their small size, weight, and power introduces its own difficulties in terms of communications, payloads, and control. Most CubeSats use either no attitude stabilization, or passive bar magnets to orient to the Earth's magnetic field. Active orientation control has been limited in the past. Current work is progressing on developing a small reaction wheel control system based on conservation of angular momentum. Testing such a system requires an extremely low friction test rig as the forces are very small. This project details the development, deployment, and refinement of a test rig suitable for CubeSat attitude control testing.

Background

- A CubeSat is a miniaturized satellite. A CubeSat is typically 10 cm^3 and weighs less than 3 lbs.
- CubeSats generally use ready-made electronics and open source programming methods.
- The purpose of the CubeSat is to reduce the cost of making and launching a satellite. Traditional satellites cost millions of dollars, whereas a CubeSat can be put into orbit for tens of thousands of dollars.
- The reduced costs of CubeSats creates opportunities for lower budget operations, such as academic institutions, to conduct extraterrestrial experimentation.

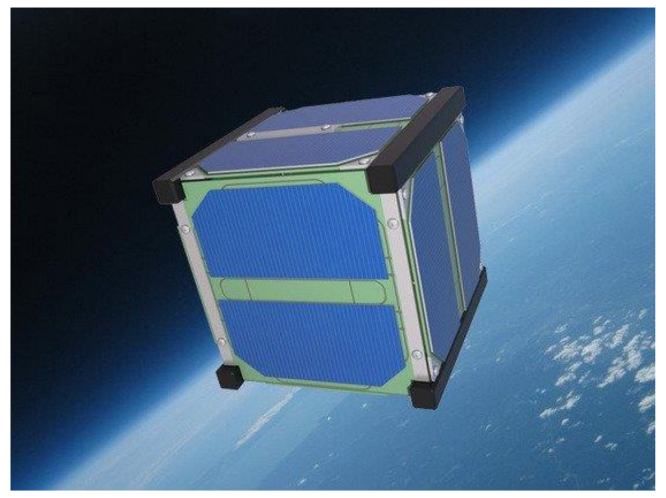

Figure 1: CubeSat

- The majority of CubeSats have been used for zero gravity experimentation and commonly neglect sophisticated orientation control systems.
- PhD student Dmitry Rivkin is doing research into developing a control system which takes advantage of conservation of angular momentum to control CubeSat orientation.
- Testing a control system requires sophisticated test rigs like spherical air bearings to mimic the outer space environment.
- Air bearings are expensive units. In order to assist Rivkin in his research, I have developed a low cost version which will allow for preliminary testing of his control system.

Methods

- I researched the structure of spherical air bearing designs. Common bearings use regulated valves and machined parts. To reduce the cost and complexity, I reduced the concept design to a pressurized chamber/base with air release holes.
- I designed the pressurized base using SolidWorks design software and made it adjustable to different size spheres(Figure 2). The base was 3D printed.

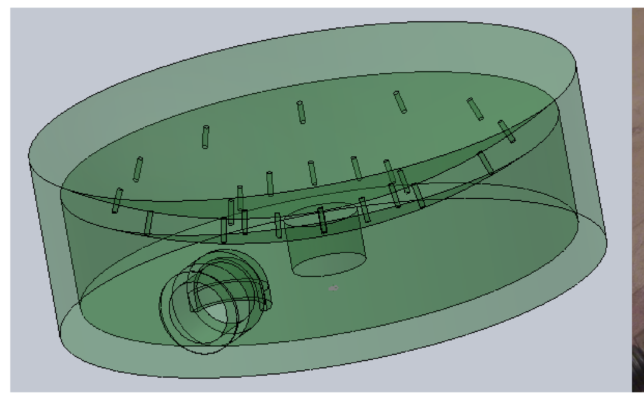

Fig. 2: Base Design

Fig. 3: Small Base

- The first construction was on a reduced scale. The base was printed to fit a 4" acrylic hemisphere and fitted with a ¼ " air nozzle.
- I constructed a rig for mounting a miniaturized version of the CubeSat. The rig had threaded extensions for balancing and upright bolts for securing the CubeSat (Figure 4).

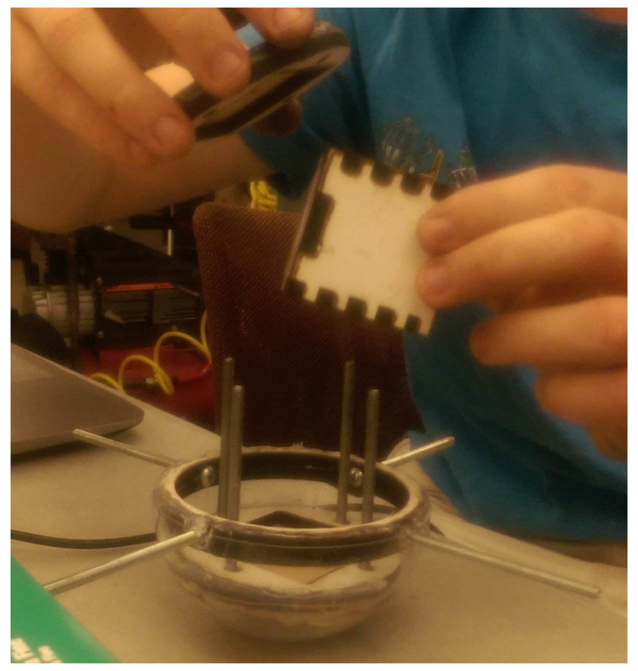

Figure 4: Mounting Rig/Mini Cube

- I wrapped the acrylic sphere in sand paper and used it to smooth the base surface. I applied coats of polyurethane and re-sanded until the functionality of the bearing was acceptable.

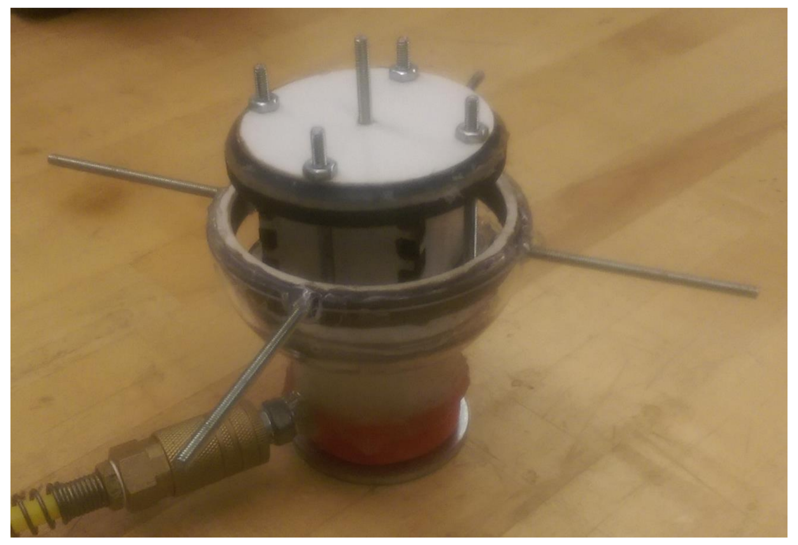

Figure 5: Small Bearing

Methods(cont'd)

- The minimum sphere size allowable for the CubeSat test rig is 7". The closest available size pre-fabricated sphere within budget was an 8" lampshade. I designed a cutting harness to cut the sphere into two hemispheres (Figure 6).

Figure 6: Cutting Rig

- I printed the base to fit the 8" diameter hemisphere.
- I expanded the design for the mounting/balancing rig to the larger scale (Figure 7).

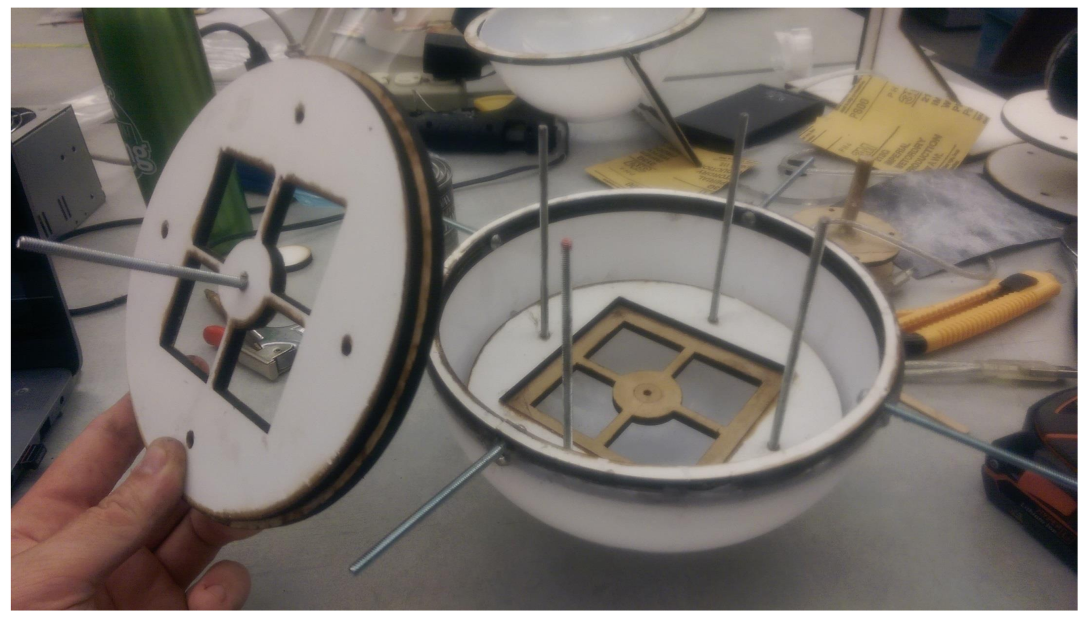

Figure 7: Large Mounting/Balancing Rig

- To increase the efficiency of the sanding process, I again attached sand paper to the sphere, and I also constructed a rig that could attach to the sphere and be inserted into a power drill (Figures 8-9). I power-sanded the base and applied polyurethane.

Fig 8: Drill Rig

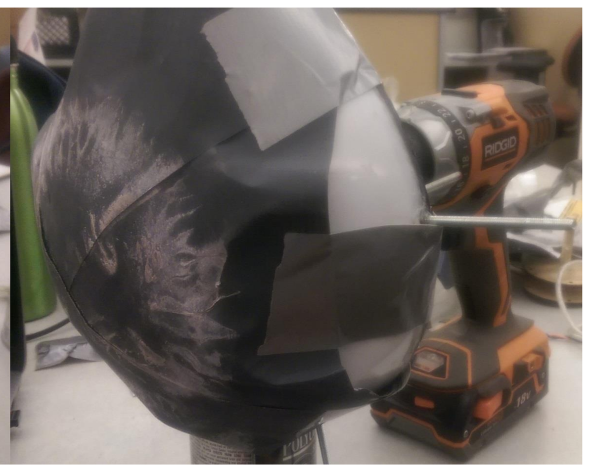

Fig 9: Sanding Sphere

- I repeated the last step until the bearing had satisfactory functionality.

Results

- The air bearing that resulted from this project is suitable for multi-dimensional preliminary testing of Rivkin's control system (Figure 10).

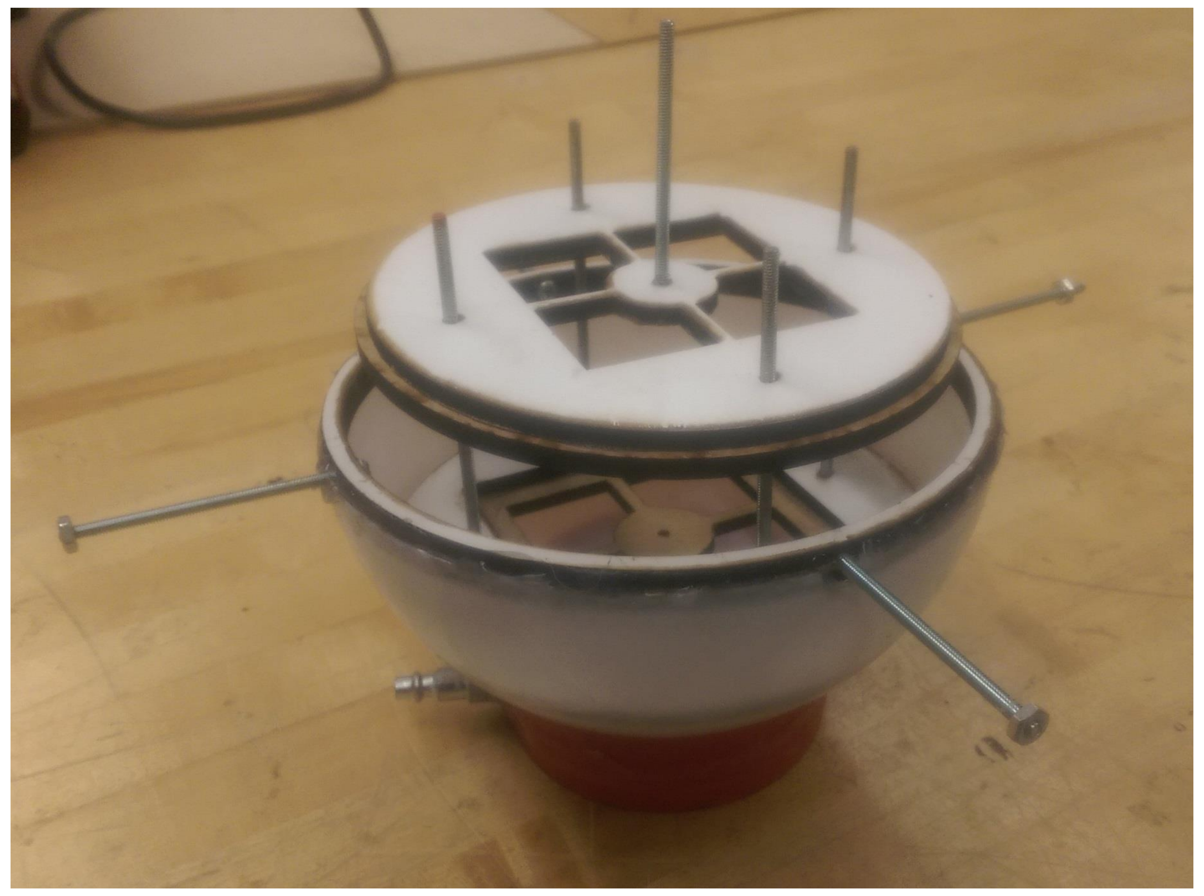

Figure 10: Final Bearing

- The bearing exhibits minimal friction and allows for 3-dimensional stabilization testing. Figure 11 depicts the insertion of Rivkin's first design of the CubeSat. This design is being used to test the control system in 1 dimension.

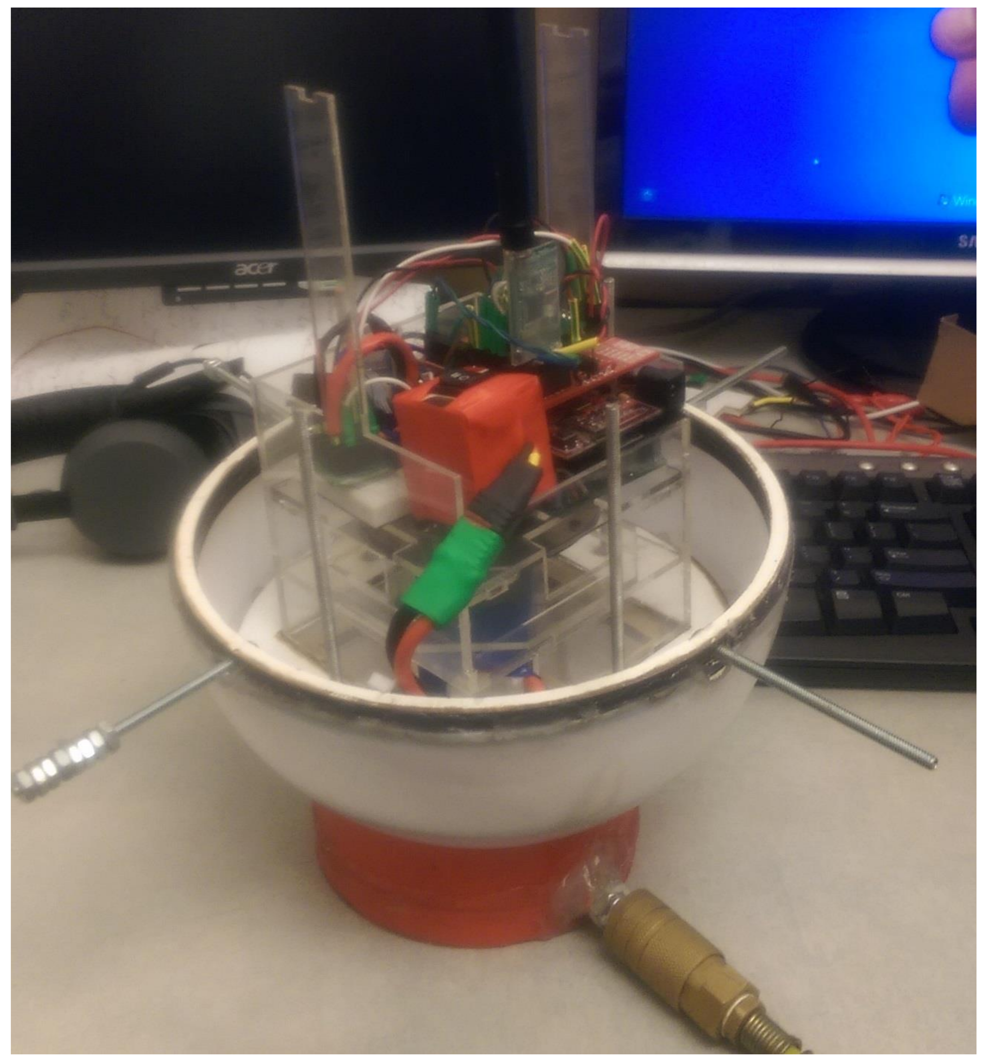

Figure 11: Air Bearing and First Satellite

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