TESTING CUBESATS WITH BALLOONS: READING DATA FROM A BALLOON SATELLITE.

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Introduction:

CubeSats. Cube Satellites, abbreviated as CubeSats, are classified as picosatellites. They are 10 cm x 10 cm x 10 cm cubes with mass not exceeding 1 kg. Projects with CubeSats began as a collaboration between California Polytechnique University and Stanford University, and roughly forty other institutions have followed the guidelines laid out by these two universities [1].

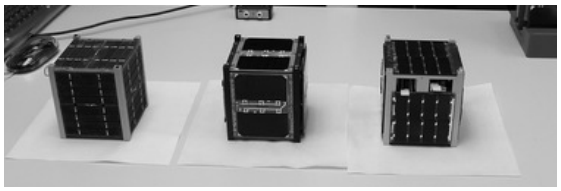

Figure 1: CubeSats [2]

With a uniform size and limited mass, multiple CubeSats can be launched at the same time, packed in and released from a standardized P-POD, or Poly-PicoSatellite Orbital Deployer (see Figure 2). The P-POD stores and protects set numbers of CubeSats during launches, and it ejects the satellites with a spring after the door has been opened.

CubeSats are a relatively affordable means to conduct experiments in space, as each unit has a launch cost of roughly $40,000 [2]. Although CubeSats are more accessible than traditional satellites, there are long wait times to be included in a launch. One method of performing tests on CubeSat capabilities in a near space environment is attaching the CubeSats to weather balloons.

Balloon Satellites. Balloon Satellites are made by attaching a payload to a weather balloon. The helium-filled weather balloons rise into the stratosphere before eventually deflating and returning to the surface of the Earth. Balloon flight tests are more indicative of how a CubeSat will perform in space than stationary or ground tests are.

Balloon satellites have lower costs than CubeSats in both development and launching. As balloon satellites are not launched from P-PODs, their dimensions are not required to be standardized. Due to their accessibility, balloon satellites have been used by hobbyists as well as students and researchers. One popular use for balloon satellites is taking pictures of the curvature of the Earth, but they can be used for a wide range of other projects. High schools students involved in the BalloonSAT Exploring Program offered by NASA's Glenn Research Center have participated in projects such as aerogel particle capture, cosmic ray detection, and solar cell measurements [3].

Launches for balloon satellites are dependent on favorable weather conditions. High winds may be enough to cancel a scheduled flight, out of concern for the payload, or the travel of the weather balloon. After a launch, balloon satellites are tracked and retrieved where they land. Surrounding terrain and the ability to retrieve the satellite must be considered when choosing a launch site.

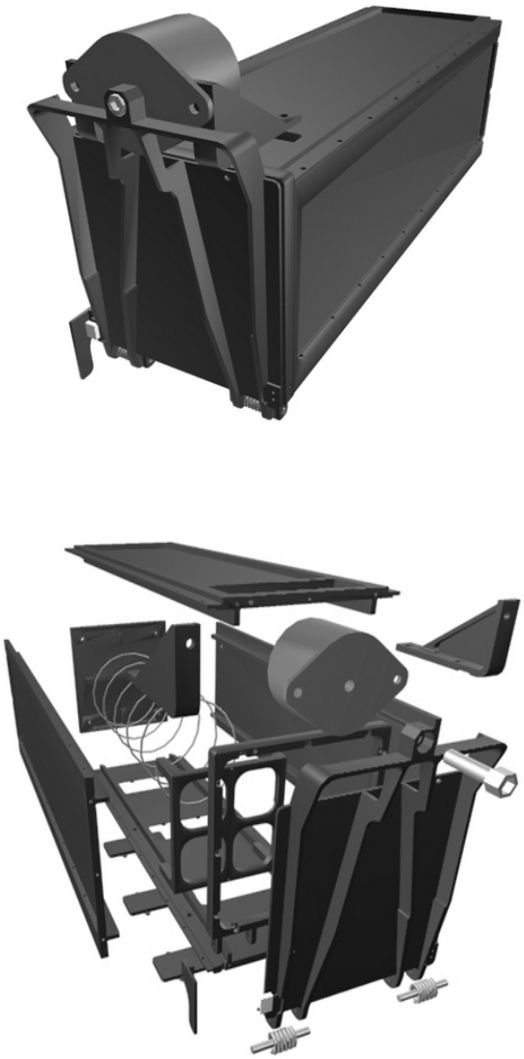

Figure 2: P-POD Renderings [2]

Set-Up:

Printed Satellite. We use a balloon satellite printed three dimensionally with the thermoplastic acrylonitrile butadiene styrene (ABS) plus. The satellite follows the 10 cm x10 cm x10 cm standard specified for a CubeSat. At present, the satellite has the ability to record temperature and pressure, which can in turn be used to find the altitude. The data collected is written to memory along with a timestamp, so that the information can be read after the retrieval of the satellite.

Programs. The satellite's circuit board is programmed with Basic to allow data collection and reading to begin or end, and to allow the setting of the satellite's clock or sampling interval. National Instruments' LabView has been used to allow a user to interface with the satellite, and to automatically set the time and date of the clock by pulling the time from a computer connected to the satellite through an RS-232 serial port.

Data collected by the satellite is recorded in 10-bit format. Another program written in LabView is used to convert information from the satellite's memory into a spreadsheet of the data in decimal format. Table 1 contains three samples taken in lab. Table 2 is the same data in decimal format.

Table 1: Data Read from Satellite (10-bit Format)
The row after the page number (page *n* corresponds to the n^{th} sample starting from 0) gives the date and time of collection.

Page0							
4	6	23	11	13	15	51	0
0	0	0	0	0	0	0	0
0	0	1	95	3	215	0	150
0	33	0	0	0	0	0	0
Page1							
4	6	23	11	13	15	52	0
0	0	0	0	0	0	0	0
0	0	1	95	3	215	0	150
0	33	0	0	0	0	0	0
Page2							
4	6	23	11	13	15	53	0
0	0	0	0	0	0	0	0
0	0	1	95	3	215	0	150
0	33	0	0	0	0	0	0

Table 2: Data in Decimal Format
The page number is in the far left column, followed by the date. The time in the third column has been converted to the time (in seconds) elapsed since the first sample time.

0	6/23/2011	0	0	0	0	0	0	351	983	150	33	0	0	0
1	6/23/2011	1	0	0	0	0	0	351	983	150	33	0	0	0
2	6/23/2011	2	0	0	0	0	0	351	983	150	33	0	0	0

Inside the Balloon Satellite. Only one circuit board is currently being used in the balloon satellite. There is enough space for another circuit board, allowing for more sensors in the satellite. One possible addition to the satellite is a GPS receiver, which would provide information about the satellite's latitude, longitude, and altitude matched with the time of each measurement throughout the flight.

The volume, mass, and energy consumption of anything added to the balloon satellite must be considered. On land, the satellite can be attached to a power source, but during flights, a battery must be included within the satellite.

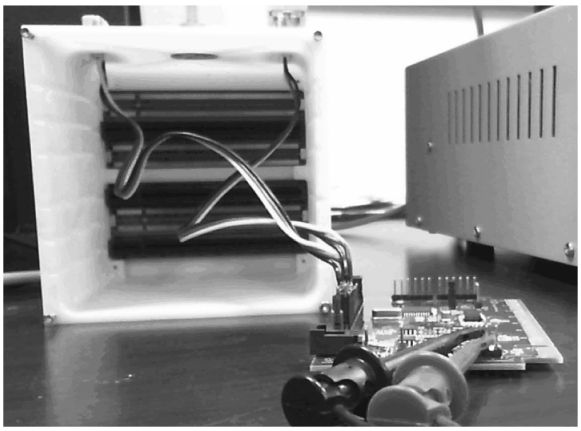

Figure 3: ABSplus CubeSat with Circuit Board

Conclusions: The ABSplus balloon satellite models a CubeSat. In the near space environment of the stratosphere, tests can be performed on the balloon satellite to discover and correct problems that the CubeSat may face. Data about a balloon satellite's flight may be stored in the memory of a circuit board and later analyzed in lab.

References: [1] A. Toorian, E. Blundell, J S Suari, R Twiggs (2005) *Cubesats as Responsive Satellites* [2] CubeSat *In the News.* Web. 18 July 2011. http://www.cubesat.org/index.php [3] "NASA - Students Send Balloons to the Stratosphere." *NASA - NASA.gov*. Web. 18 July 2011. <http://www.nasa.gov/centers/glenn/technology/explorers_balloons.html>.

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