Dartmouth Greencube 3

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Final Report
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A. OBJECTIVES

The goals of the GreenCube project are (1) to maintain a scientifically interesting, student-driven balloon-borne CubeSat program in Dartmouth Physics; (2) to incorporate new design features into small payloads for Low Cost Access to Space (LCAS) class auroral sounding rocket proposals by Professor Lynch; and (3) on a longer timescale, to incorporate designs into Professor Millan's future plans for small orbiters, which potentially could include student-designed CubeSats. (Professor Millan is also at Dartmouth College and PI of the NASA BARREL mission).

With GreenCube 3 the group began a project with the eventual goal of improving the calibration of telescopes. We will fly a calibrated light source that can be tracked using a telescope on the ground (see Figure 1). This way we can determine and account for the effects of atmospheric variations on images taken by the telescope. Goals of GreenCube 3 included the development and/or testing of a light source, tracking program, and new telemetry system.

Because the ultimate goal of the GreenCube program is to launch and operate fully functioning plasma science payloads into orbit, we have started to address some of the challenges involved with keeping a number of small satellites in orbit capable of performing meaningful science missions. This last goal will be addressed more fully with GreenCube 4, but we have made a start while waiting for launch conditions to improve enough for us to continue with GreenCube 3.

B. APPROACH AND RESULTS

To fly a calibrated light source with well-defined brightness, the team first needed to accurately determine, and minimize, the spinning and rocking motions of balloon payloads during flight. A de-spinning bar was added to the flight train that allows the payloads to be suspended from two points rather than just one point along the central axis. The students developed a new radio system with a higher data rate than previous Greencube experiments (1-second cadence instead of 6-second) to reduce aliasing in the magnetometer data. An accelerometer was added to the payload to provide more data about its motion.

The students designed and built an LED circuit (Figure 2) to provide a blinking light source for a ground telescope to image. The LEDs flash at 2 Hz with approximately a 10% duty cycle. The group also developed a program in Matlab to take real-time GPS coordinates transmitted via radio from the payload and use them to point the telescope toward the payload.

The team conducted an initial GreenCube3 test flight in the summer of 2010. Two adjacent Greencubes were flown on two high altitude sounding balloons which reached approximately 90,000 feet altitude before bursting (see Figure 3). The payloads then descended via parachute and were retrieved using the real-time GPS track received through the ham radio system. The balloons flew over the Presidential Range of mountains and were recovered in Maine. The flight time was approximately two hours. One payload contained our LED circuit and new (Zigbee) radio system, while the other payload used an identical setup to our previous mission, GreenCube 2. A system to predict landing location was developed for this project that uses the GPS data from the payloads to plot in real time where the balloons are (green trace on image in Figure 4). Then, based on an average of the slopes between the last 10 points, we extrapolate out and predict a landing position (purple dot), which is updated with each new data point received.

The LEDs on the payload were visible in the telescope field of view for several minutes continuously near the beginning of the flight, until an unforeseen Matlab problem crashed the tracking program; we were not able to restart the tracking program before the balloon was too far away to image. The team also experienced problems with the new radio system, possibly due to the lack of maintaining a direct line of sight from the ground station antenna to the payload.

The students had planned to fly a second test flight in the Fall to answer unresolved questions about the effectiveness of the tracking program and the reliability of the new radio system over long distances, as well as to collect more data about payload spinning. The second test flight had to be postponed to wait for improved weather. We hope to complete this test-flight phase of GreenCube3 in the early spring, followed by another flight related to the GreenCube3 science goals (sky brightness and telescope tracking) later in the spring or early summer.

In February 2011, while the test flight was on hold, one of the Lynch Rocket Lab's students conducted a related mission at the Mars Desert Research Station (MDRS) where he was working for two weeks. MDRS is an outpost located in the remote desert of Utah, where the terrain, geology and weather are similar to those present on Mars. The outpost is used to: (1) identify the challenges that would confront the first humans to explore the red planet, and (2) serve as a test bed for technologies that could aid in the future exploration of Mars. It was this second goal to which GreenCube 3 contributed.

Meteorological packages (like GreenCube) on tethered balloons can be used to explore the seasonal dust storms on Mars and other atmospheric phenomena. Greencube 3 was also designed to operate untethered, but prevailing winds at the MDRS prevented this. Nevertheless, even in a tethered configuration, a great deal of valuable data was obtained. The tethered payload was imaged from the ground for an extended period of time by the Musk Observatory, which provided a field demonstration of the ground based tracking of an on-board calibrated light source. Photometric data of the on board LEDs was gathered at multiple distances as the payload anchor site was moved (Figure 5), and GPS and temperature data were relayed back to the ground via radio. In addition, the payload was deployed and launched following MDRS's "in simulation" rules, which are in place to maintain the applicability of the experience to a true mission to Mars. The balloon and tethered payload were inflated and launched by only two participants, who wore bulky EVA suits and gloves during the entire process. Thus, in addition to contributing to the primary science goals of the GreenCube project, our experiences at MDRS have indicated that high altitude balloons can be deployed on manned missions to Mars, and are an effective means of investigating the atmosphere of the Red Planet.

Finally, the students have begun to pursue the goals of GreenCube 4, investigating the challenges involved in adapting our balloon-borne project to an orbiting satellite mission, while waiting for the right launch conditions to continue with GreenCube 3. One of our senior students has chosen to do an honors thesis on designing a method of keeping these orbiting satellites in a small cluster. In order to be a viable testing platform, the satellites must fight the tendency to drift apart caused by their initial injection velocities from their launch vehicle, to maintain a loose formation for the entire mission. The formation has very limited available fuel storage as the satellites are quite small. We are studying how a consensus control algorithm may allow the satellites to form a loosely-connected flock in orbit using limited fuel. In the proposed system, each satellite will communicate only with its closest neighbors. The individual agents in the system, given a group objective, will maintain a loose flock formation and prevent the agents from drifting too far out of their desired orbital planes. If this objective is achieved, the satellites will fly through the Northern auroral zone every 90 minutes, providing our lab with a plethora of useful science data.

Several of the students have been learning about the use of solar panels as a power source for a satellite mission. We have been investigating charge-controller circuits and learning about solar panel diagnostic techniques like IV-curves to test panel health and efficiency. We have practiced plotting some IV-curves of our own (see Figure 6), for both healthy and damaged solar panels. The group has also been working on a possible redesign of our payload's control board.

C. SIGNIFICANCE OF RESULTS

The GreenCube team met its GreenCube3 science goals by designing and implementing a system that enables a telescope to image a light source on our payload during flight. We have also begun working towards the goals of GreenCube 4 by investigating solar panels and flocking algorithms, both of which we would want to use for an orbital mission.

The GreenCube program addresses JPL's interests in enhancing student preparation for a professional career in space systems/science at JPL or elsewhere. The students have gained experience with instruments of particular interest to JPL, such as GPS; magnetometers; and solar panels, as well as with analysis techniques for multi-point in-situ geophysical observations.

D. NEW TECHNOLOGY

N/A

E. FINANCIAL STATUS

The total funding for this task was $21,000, all of which has been expended.

F. ACKNOWLEDGEMENTS

This report was assembled and written by the following students, with minimal editing and overview by Professor Lynch: Amanda Slagle (project manager), Will Voight (recovery tracking program), Ben Feintzeig (telescope tracking program), Sean Currey (flocking program and flight data analysis), Jon Guinther (recovery team lead, and new smart-phone programming), Max Fagin (MDRS student), Casey Bradshaw (predictions and logistics), and first-year students Patrick Yukman, Ruosi Zhou, and Thomas Whalen.

G. PUBLICATIONS and PRESENTATIONS

[A] Amanda Slagle, Phillip Bracikowski, Sean Currey, Kristina Lynch, Umair Siddiqui, Max Fagin “GreenCube 2: Multiple Balloon Measurements of Gravity Waves over New Hampshire,” poster, CalPoly CubeSat Developers’ Workshop, April 21 – 23, 2010.

[B] P. Bracikowski, K. A. Lynch, L. Gayetsky “Low-Resource CubeSat-scale Sensorcraft for Auroral and Ionospheric Plasma Studies,” proceedings, 24th Annual AIAA/USU Conference on Small Satellites, August, 2010.

H. REFERENCES

None.

I. FIGURES

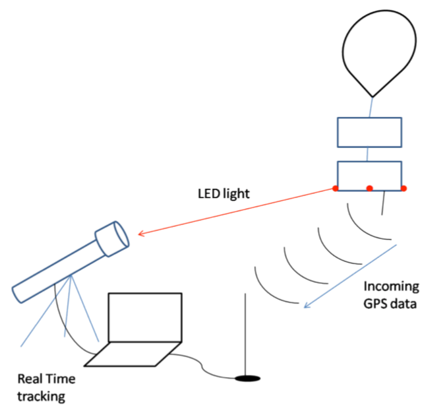

Figure 1. A light source on our payload that can be imaged using a telescope, which is pointed using real-time GPS data.

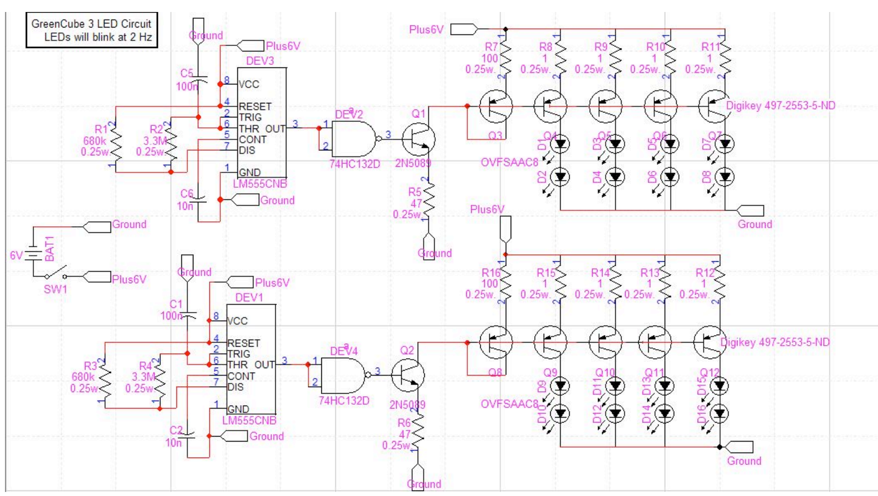

Figure 2. The schematic above shows the circuit designed to make a bank of LEDs flash at about 2Hz.

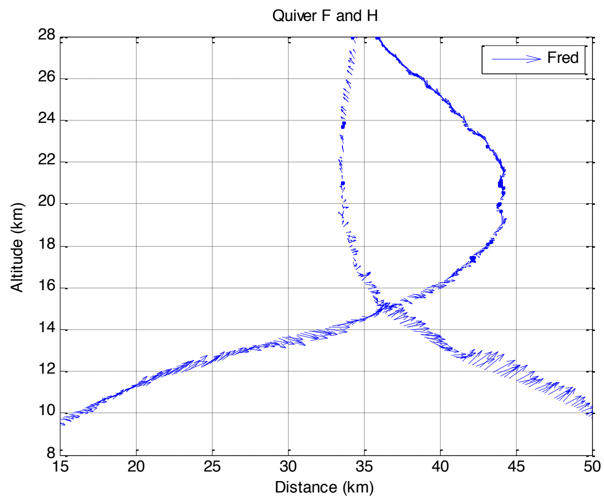

Figure 3. Trajectory plot of the “Fred” payload (the one with LEDs, accelerometer, and new radio system) from the summer 2010 flight. The vector magnitudes in the x and y directions indicate along-trank and across-track velocities, respectively.

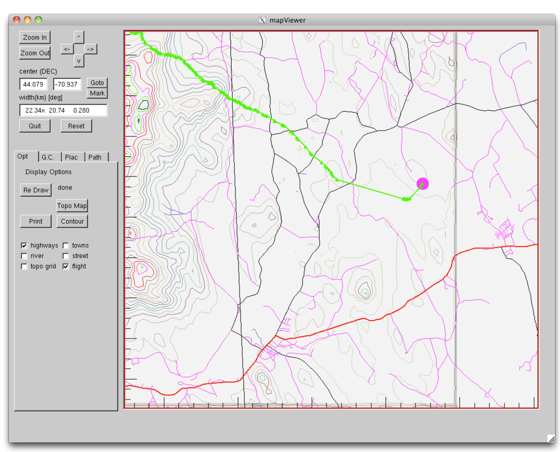

Figure 4. The interface for a program to aid in the tracking and recovery of balloons. The green trace on the map shows the balloon’s flight path as given by its GPS coordinates. The purple dot shows the predicted landing position, which is extrapolated from the current flight path and updated whenever new data is received.

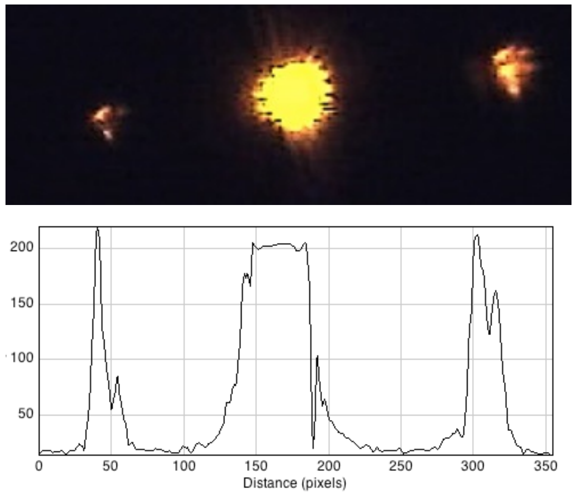

Figure 5. A sample of the ground based images and photometric data obtained of the light source on board GreenCube 3.

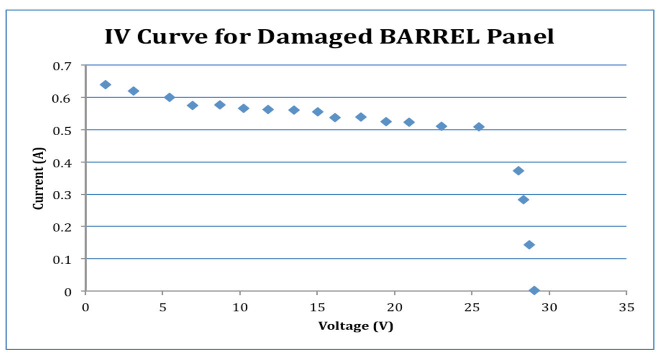

Figure 6. IV curve for a damaged solar panel from Professor Millan's BARREL project.

K. COPYRIGHT STATEMENT