Assigned Proposal Number:_____

Strategic University Research Partnership Proposal for FY2010
Due Date: October 2, 2010, by 4 PM PST

1. Title of Proposal

Dartmouth GreenCube3

2. JPL Principal Investigator
Anthony J. Mannucci

JPL Org. No.: 335G

3. Co-Investigator(s) (University and JPL Co-Is)

Kristina Lynch
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4. Total Budget Request for FY10 (check one box)

New Proposal [ ] Renewal Proposal [X]

Budget Request: $25,000

5. Student Participants
Sean Currey, undergraduate
Sean.R.Currey@Dartmouth.edu
Umair Siddiqui, undergraduate
M.Umair.Siddiqui@Dartmouth.edu
Amanda Slagle, undergraduate
Amanda.K.Slagle@Dartmouth.edu

6. Topic Area— Place a "1" next to your primary area and a "2" next to your secondary (optional) area. Hint: Delete unused topical areas to recoup space.

1. Next Generation Leaders and Innovators
[1] Education and training
[2] Student career path development

7. Objectives— State clearly and concisely the objectives of your work and why it is important technically and programmatically.

Overall longterm objectives of GreenCube program:

The GreenCube project stems from Prof Lynch's interest in small, autonomous science payloads for multipayload auroral sounding rockets, and from Prof Millan's interest in small, cubesat-like orbiters for future science missions. It is feasible because of the undergraduate students who have been working in our labs for several years, who have taken the shop course and have become familiar with electronics by working on our grant-funded rocket and balloon programs. It is different from these same students working on grant-funded research because it is subject to their own deadlines and structure, and driven by their own interests.

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 LCAS-class auroral sounding rocket proposals by Prof Lynch; (3) on a longer timescale, to incorporate designs into Prof Milllan's future plans for small orbiters, which potentially could include student-driven cubesats.

Status of GreenCube program as of fall 2009:

The GreenCube, which was designed and built over the last few years by Dartmouth undergraduates with JPL SURP support, consists of a single board computer (designed by the students with mentoring from our engineers) with power handling, data handling, and digitization of analog inputs, a GPS system, a ham radio system, a 3-axis magnetometer, and several thermistors and other monitors. The GreenCube2 program which flew in the summer of 2009 (under 2009 SURP support) was a step forward from the original GreenCube in having (a) a science goal rather than a purely technology development one, and (b) two copies of the GreenCube flown in tandem for multipoint measurement. The students spent the winter term debating various possible science missions for the GreenCube infrastructure, and settled on two-point

measurements of atmospheric winds and temperature for a study of orographic gravity waves. They found that preliminary measurements from the GreenCube1 flight GPS system showed indications of gravity waves in the wind velocity measurements; determined that a higher data rate was necessary and increased it from a 30-sec cadence to a 6-sec cadence; revisited the temperature measurements from GreenCube1 and changed the circuitry to support exterior thermistor measurements; built a second copy of the GreenCube; and launched, flew, and recovered both payloads in August of this year. Questions about the parameters of the gravity waves were partially addressed pre-flight using the JPL database on GPS occultation measurements from spacecraft; one of the students learned to use this database and examined profiles across New Hampshire. In addition, the secondary payload on each balloon package this year was outfitted to carry a video camera, and the resulting movies (one of which is of HD quality) will be used to put the insitu measurements in context; various periods of apparent gravity wave structuring are seen in the cloud formations below the balloons during the flight. Data analysis of the flight telemetry is ongoing; the students will present a Physics Dept colloquium in November on their results.

Specifics of GreenCube3 proposed for this year (details in section 8 below):
For the GreenCube3 program, which we propose in this 2010 round of the SURP, we request funding to continue building on the success of our GreenCubes and exhibit the Cubes' efficacy in other scientific and engineering investigations. We detail this in section [8] below.

8. Technical Approach— Describe your plan to achieve your objectives. Provide specific tasks, milestones, and responsibilities.

GreenCube3 this coming year:

Last summer our successful launch of GreenCube2 (funded under last year's SURP program) demonstrated both the capability and versatility of our small high altitude balloon payloads. This year, the students will take advantage of the GreenCube2's versatile cubes both to continue examining atmospheric gravity waves, and to tackle entirely new scientific investigations and engineering challenges. The students will modify the existing payloads so that they are equipped to fly at night. The team will investigate background sky brightness using a photometer developed by astronomy faculty at Dartmouth; this photometer study was being done through a balloon launch program in Colorado but we can incorporate it into the GreenCube infrastructure. The photometer along with an upward facing camera will quantify how visible the stars are from the upper atmosphere.

The students will also improve upon GreenCube2 by devising a way to prohibit the payload from spinning rapidly during flight (see the diagram in Figure 1 at end). This will prevent the data from the onboard magnetometers from being aliased (presently the package spins faster than the 6-sec data cadence; it will also be helpful in terms of the look directions of the photometer and camera.) Separately, the team will also investigate ways to increase the flight time of the balloons near their maximum altitudes. This investigation will address possibilities and feasibility of an upper atmosphere observatory, or even a temporary cell phone relay deployed by balloon over a disaster area.

Schedule and specific milestones:

Winter term will be spent outfitting GreenCube3 with the photometer and changing the package mounting to reduce the spin frequency. We will plan for one payload launch at night during this term.

Spring term will be used to analyze the data collected in the winter and to prepare a second cube for launch. Methods of keeping a balloon in the air for longer than two hours will also be investigated.

Summer term will include a day launch and a night launch in order to quantify differences day/night in gravity wave structuring, as well as analysis of data collected from these flights.

9. Renewal Proposals Only— Describe the accomplishments of the predecessor award. If renewal is desired for continuity of graduate student research, please so indicate.

In last year's SURP proposal, we wrote: *"…we request funding for an enhanced version … in which we will re-use the successful balloon-borne version of the GreenCube but this time carrying a true science investigation rather than just the infrastructure of the Cube. … Winter term will be spent investigating the interest and feasibility of the various science investigations listed … Spring term will be used to implement and test the detector and electronics for the investigation. … Summer term will include the flight(s) and the data analysis and interpretation."* As described in section 7 above, these goals have been amply met. Data analysis is still ongoing; we hope to match fluctuations in temperature with those in wind speed to provide evidence of possible gravity wave activity (see figures at end). The students are anxious to continue the program and expand the capabilities and heritage of the GreenCube.

The figures (3-7) attached at the end of this document show the initial results and the balloon trajectories from the GreenCube2 flights in August. The students are working on data analysis now and will present their results at a department colloquium in November.

10. Innovative Features— Describe new concepts that are being applied to produce a evolutionary or revolutionary advance.

We continue to find that the GreenCube project is surprisingly rewarding and effective as a teaching and learning tool. The combination of training that our rocket and balloon lab work gives the students, with the enhancement of then letting them go on to design and run their own investigation, seems to be working well. The GreenCube program is developing a cadre of capable interested students and is now becoming a science project instead of "just" a technology development project.

For the projects proposed for GreenCube3, the students will expand on the existing capabilities of the GreenCube infrastructure. What they find will contribute both to on ongoing astronomy observational question at Dartmouth, and to open questions in gravity wave propagation and behavior.

11. Team Strengths— Describe the strengths each member of the team brings to the proposed effort.

The GreenCube project is an offspring of existing work at the Lynch rocket lab and the Millan balloon lab, and takes advantage of the lab facilities and student training in place for those larger grant-funded projects.

All the items listed in the sections above will be done at Dartmouth, under the auspices of Prof Lynch's rocket lab and Prof Millan's balloon lab. Engineering mentorship will be provided by Dr Kevin Rhoads, Mr David McGaw, and Mr David Collins, who are all engineers in our groups, and by Mr Dwayne Adams, who is the machinist in the Dartmouth Science Division apparatus shop. We look to JPL for suggestions about possible subsystems for the payloads and for guidance with the satellite-based GPS occultation data sites.

12. Exchange of personnel— Describe any plans to have work performed at JPL by university personnel or at the university by JPL personnel. Commitment by the appropriate JPL and/or university organization to host the proposed personal exchange must be obtained and so stated in this section. For Research Initiatives, please indicate whether a linked student internship is proposed.

N/A

13. Impact of Results on JPL Missions and Programs— Describe how this work maps into the strategic topical areas.

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

14. Plans for Follow-on Funding— Provide a realistic assessment of future funding potential. Discuss how this proposal may enhance the probability of such funding.

The near-term goals seen as extensions to this seed project include both NASA/LCAS sounding rocket science proposals, and the NSF CubeSat program. The SURP funding we have already received has gotten the Dartmouth CubeSat program established as a balloon-borne student program. This is critical before a full-up science investigation could be competed; it also in and of itself is a worthy student-based project. Our GreenCube program is now moving into the realm of science investigations, and is developing a solid base of interested students involved in the program. In parallel, we are also using NH state EPSCOR funding to investigate the incorporation of CubeSats and PPods onto sounding rocket platforms; this project, maintained by a previous GreenCube undergraduate who is now a master's student here, is running this year in parallel with our balloon-borne SURP projects.

15. Budget— Please complete the budget sheet below. Contact your Section Administrator or Business Administrator Manager for FY10 rates and for assistance in filling out the form.

16. Partner contract administrator contact information— Provide name of contract administrator, address, phone number, and email.

Nancy Archibald
Trustees of Dartmouth College
Office of Sponsored Projects
11 Rope Ferry Road #6210
Hanover, NH 03755-1404

Sponsored.Projects@Dartmouth.edu 603-646-3007

17. JPL Principal Investigator Signature

Name: Org:

Signature: _____ Date: _____

18. JPL PI Division Manager Signature

Name: Org:

Signature: _____ Date: _____

19. University Co-Investigator Signature

Name: Kristina Lynch

Signature: _____ Date: _____

20. University Representative with Signature Authority

Name: L. Shea McGovern, Asst. Dir., OSP

Title:

Signature: _____ Date: _____

Figures, Graphics, Tables, etc.

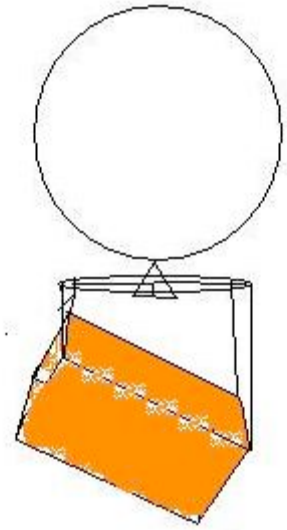


Figure 1: balloon with structure for stabilizing payload and producing correct photometer field of view

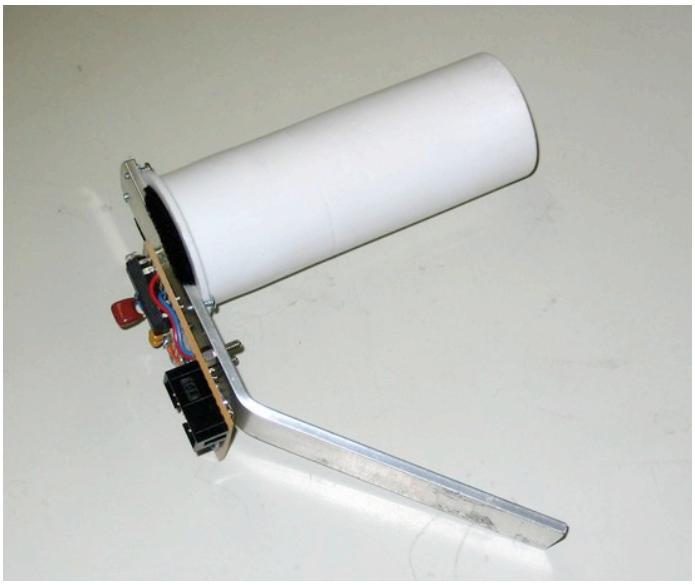


Figure 2: Photometer, courtesy of http://yorkebrown.net/balloon/photometer.htm

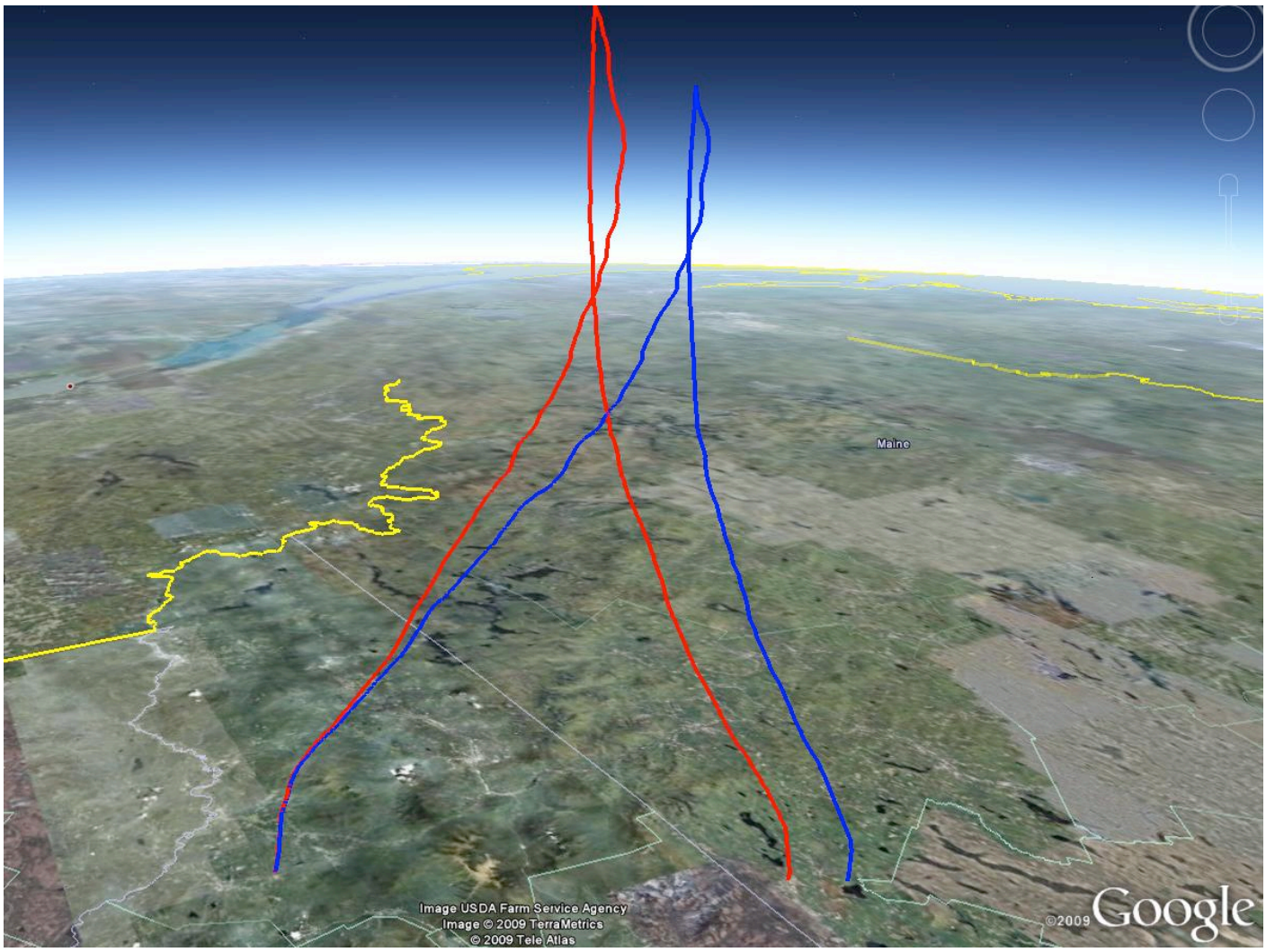
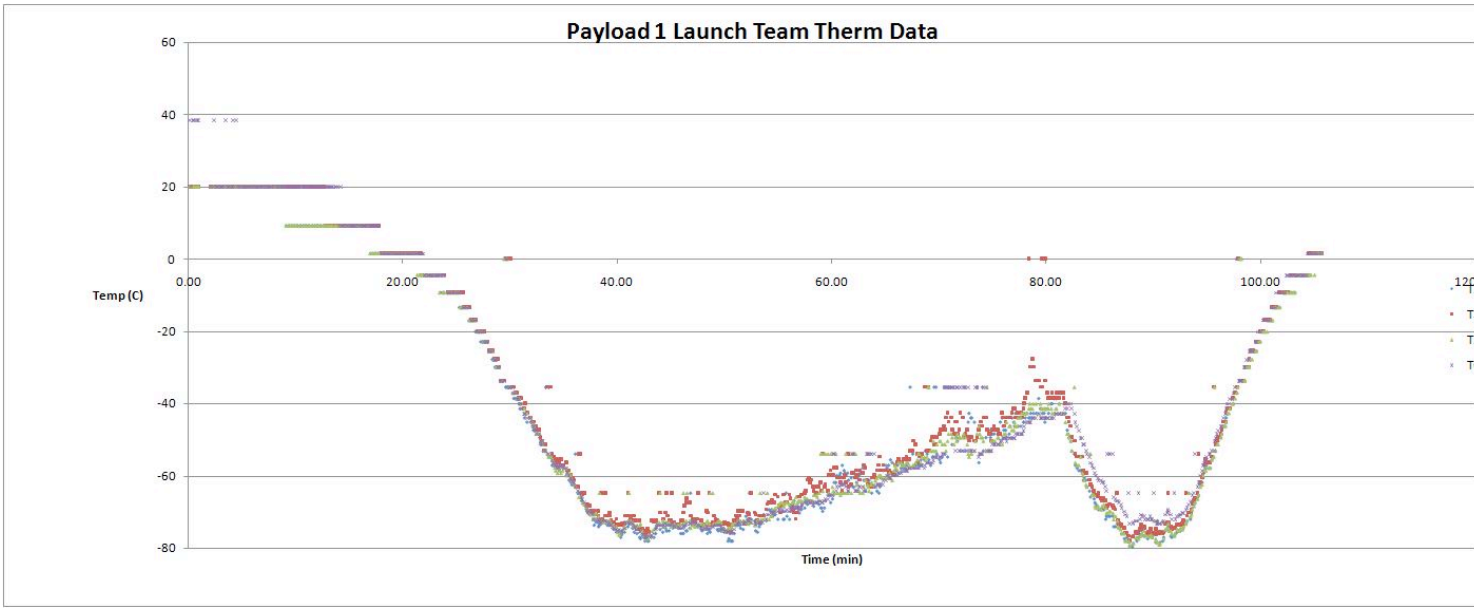
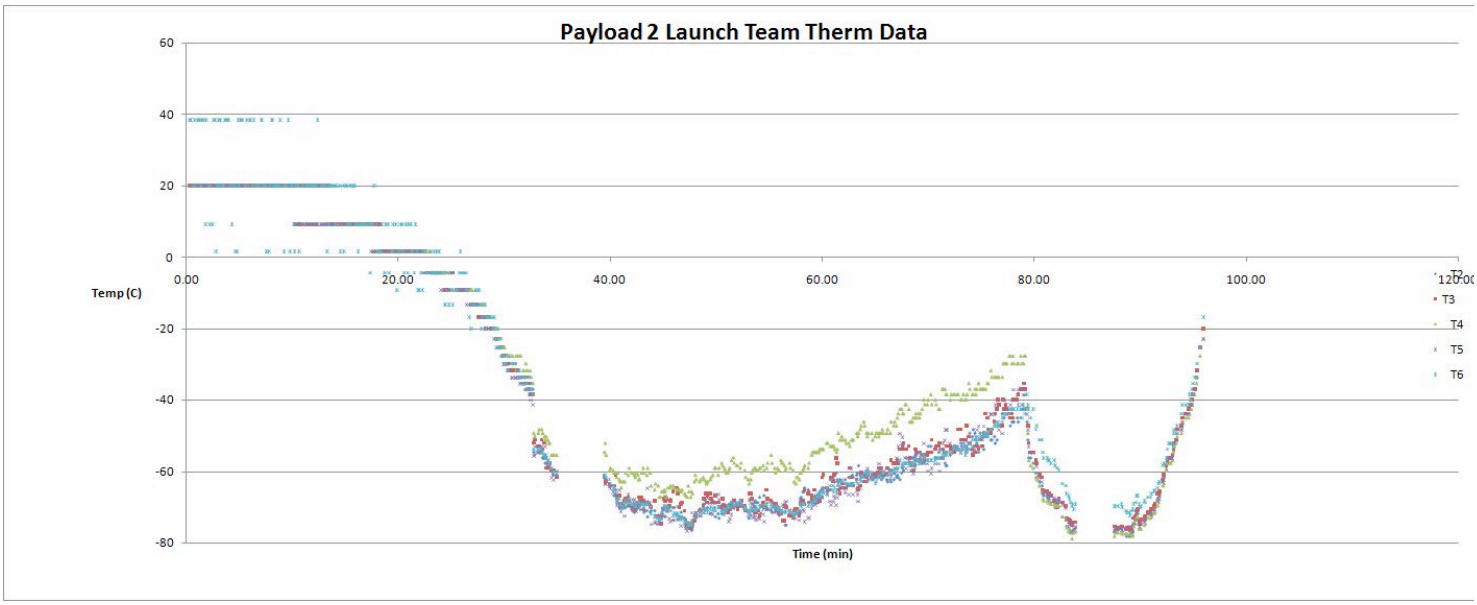
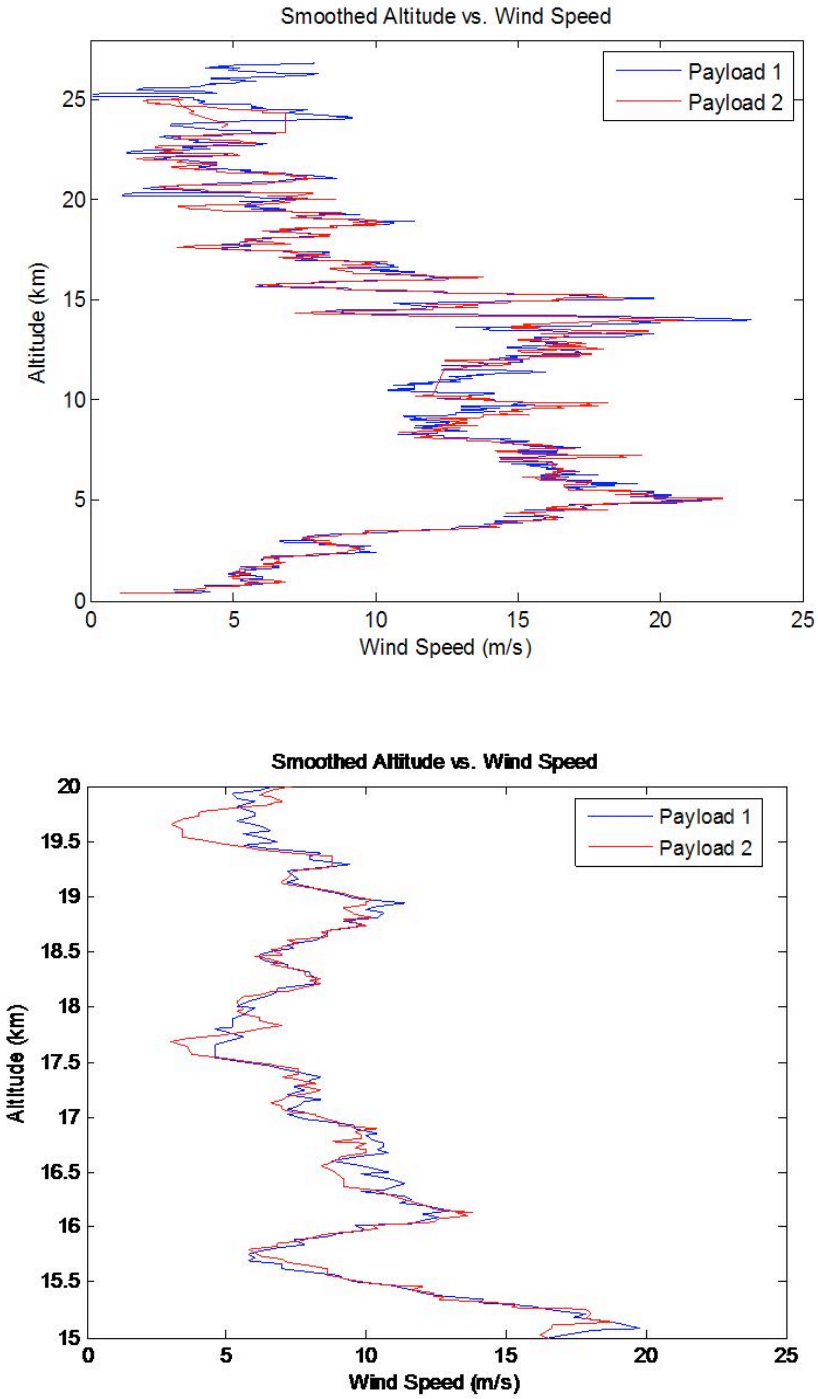


Figure 3: GoogleEarth image of GPS data received from the two GreenCube2 payloads.





Figures 4 & 5: Temperature data collected from GreenCube 2.



Figures 6 & 7: The upper figure shows a moving average of the balloons' horizontal velocities during the their ascent. The lower figure shows just a small portion of the same plot. The differences in velocity could be attributed to either a propagating gravity wave feature or to the displacement between the two balloon trajectories.

SURP Budget Sheet

Category	At JPL	At External Institution(s)
DIRECT COST		
1. **Salaries**— *A. J. Mannucci, JPL PI, 16 hours*	$1,400	$8,038
2. **Labor Fringe Rates**— *Employee Benefits*	$700	$1,553
3. **Cat A Labor**— *(Itemize) (Only "itemize" the person names or job classifications and the number of hours for each. You can show one total $ figure for labor.)*	$0	
4. **Procurements—Equipment, Materials and Supplies** *(Itemize). JPL - Do not list the contracts for outside collaborators. This total is on line #12 on the external collaborator column.*	$0	$2,500
5. **Procurements— Subcontracts** *(PS – contracts other than with university)* a. Student Internship $ _____ see 2010 Call Guidelines b. Other contracts (itemize) $ _____	$0	0
6. **Services**— (Itemize) *(JPL be sure to include in-house services at JPL)*	$0	0
7. **Domestic Travel**— *Itemize where and why*	$0	$1,200 AGU
8. **Other**—*(Itemize) (Chargebacks, etc.)*	$100	0
9. **Total Direct Costs** *(total of dollars 1 through 8)*	$2,200	$13,291
10. ALLOCATED DIRECT COSTS (ADC)	$1,800	
JPL see your Section Administrator or Business Administration Manager for current rates. ADC costs are calculated on JPL's total direct costs (Item #9) and the external institution(s) budget (item #12). ADC at JPL consisting of: a. Labor ADC $500 b. RSA Contract ADC (university)* $1,100 c. CREI Contract ADC (internship) $0 d. Other Contracts ADC $0 e. Purchase Orders ADC $0 f. General ADC $200 Enter total on Item #10 $1,800 *Important— If hardware or software deliveries are part of proposed effort or if GFE is provided to the university, then CREI Contract ADC must be applied.		
11. **Overhead— external Institution** *Itemize as appropriate here and enter total*		$7,709 58.0%
12. **Individual Budgets** *JPL add Item #9 and Item #10 for total JPL budget* *External Institution add Item #9 and Item #11*	$4,000	$21,000
13. **Total Combined Budget**** *JPL Budget plus External Institution Budget*	$25,000	

**If a student summer internship is proposed, you may exceed the $100,000 cap for a Research Initiative by the cost of the internship, including ADC (sum of Item 5a and 10c).