Assigned Proposal Number: R29

Strategic University Research Partnership Proposal for FY2011
Due Date: October 1, 2010, by 4 PM PDT

1. Title of Proposal

Dartmouth GreenCube4

2. JPL Principal Investigator
Anthony J. Mannucci

JPL Org. No.: 335G

3. Co-Investigator(s) (University and JPL Co-Is)
Kristina Lynch, Robyn Millan
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4. Total Budget Request for FY11

New Proposal [ ] Successor Proposal [xxx]

Budget Request: $25,000

5. Student Participants
Amanda Slagle, Jon Guinther, Alannah Linkhorn, Casey Bradshaw, Will Voigt, Ben Feintzeig, Max Fagin, Sean Currey (all Dartmouth undergraduates; Max Fagin is a 5th year BE student); 2 new students will be retained in the winter term under the Dartmouth WISP (Women in Science Program) as Amanda, Alannah, and Casey have been in past years. (All student emails are first.last@dartmouth.edu)

6. Topic Area— Place a "1" next to your primary area and a "2" next to your secondary (optional) area. Tip: 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 the expected deliverables.

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 2010:

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. In Fall of 2009, the GreenCube students presented a department colloquium on the GreenCube2 flight, a pair of instrumented balloons flown together to investigate signatures of gravity waves over Mt Washington. At that time, having shown that the GreenCube infrastructure was capable of scientific investigation, the students in the group

decided to focus the GreenCube3 flights on a science project of their choice, an astronomy project.
Thus for GreenCube3, the students modified the existing payloads so that they are equipped to fly at night. Their goal is to investigate background sky brightness using a sensor developed by astronomy faculty at Dartmouth; this study was being done through a balloon launch program in Colorado but we have incorporated it into the GreenCube infrastructure. The goal of the study, somewhat modified and improved from the original proposal, is to fly a calibrated light source and track it using a telescope on the ground which is steered by the received real-time GPS data from the balloon.

The students improved upon GreenCube2 by devising a way to prohibit the payload from spinning rapidly during flight (see the diagram in the figures at end). This prevents the data from the onboard magnetometers from being aliased (in the original design, 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.) Also, a set of bright and flashing LEDs was mounted to the secondary package for tracking by the ground telescope. In addition, the students incorporated a second telemetry system (a "Zigbee" radio) with a much higher data cadence than the ham radio allows. Originally it was thought that this radio would replace the ham radio but one of our lessons learned from this summer's flight was that the GPS data is best maintained on the ham radio, for various reasons; while the science data can be transmitted at a higher rate on the Zigbee.

At the time of this writing (Sept 2010), we are still midway through our goals for GreenCube3 (which has budget dates from February 2010 through February 2011.) We have had one flight of the improved (and telescope-tracked) GreenCube (named Fred) in parallel with the original design (named Henry); in the process we have had a significant overhaul of the student groups this year, with several of the original students (Phil Bracikowski and Umair Siddiqui, both graduating Dartmouth in summer 2010) spending time mentoring and training several new students (Alannah Linkhorn, Jon Guinther, and Casey Bradshaw). The new students and the new design both benefitted from our flight this summer; we have many lessons learned and we will have a second test flight early this fall term. Then the plan is to have the full-blown GreenCube3 flight, with the calibrated light source instead of the test-round of LEDs, late this fall term.

Specifics of GreenCube4 proposed for this year (details in section 8 below):
For the GreenCube4 program, which we propose in this 2011 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.

Overview
There are several new initiatives to pursue with GreenCube4, together with continued work on the GreenCube3 astronomy sky brightness project and GreenCube2 gravity wave project. We will assess at the end of this fall term the success and status of the sky brightness project and decide at that point whether and to what extent to continue it into the the GreenCube4 year. Since all of our balloons provide GPS data for tracking, we continue to add to our database of atmospheric velocity profiles, which were the focus of GreenCube2, with each flight. New initiatives for GreenCube4 include (a) an investigation of solar panel power handling, a new regime for our group; and (b) the possibility of a launch from the Mars Desert Research Station, as an outgrowth of one of our student's NASA internship this summer. Finally, (c) the students maintain an interest in exploring the possibilities of using the balloons as temporary emergency cellphone repeaters.

(a)
One of our long-term goals is to propose a CubeSat science mission to the NSF Cubesat program. In order to extend the capabilities of GreenCube to longer flights, a solar power system will be necessary. Until now, GreenCube has utilized batteries for its several-hour-long flights. Prof Millan's group has experience using solar power on balloon flights, and has the experience to know how important it is to demonstrate that the

photovoltaic (PV) panels will function in the extreme environmental conditions experienced in space. For example, since the temperature of solar cells in the space (and balloon) environment are controlled primarily by radiation, temperatures can swing between -40C to +100 C several times an hour. The opportunity to develop and test our solar panel design in a realistic space environment will greatly enhance our chances for a successful CubeSat proposal and ultimately a CubeSat mission.

In Fall 2010, Prof Millan's group will identify several candidate approaches, including purchasing off-the-shelf PV panels (such as Clyde Space), and in-house construction of panels from individual cells. They will also solicit feedback from colleagues who have used both kinds of systems. As part of GreenCube4, we will begin lab testing of the panels in the winter and integrate the full power system in the spring in time for a summer test flight on a balloon.

(b)
One of our students, Max Fagin, participated in a NASA Ames internship this summer. As a result of that, he and several of his internship colleagues are scheduled for a rotation at the Mars Desert Research Station (MDRS) this winter, from 29 Jan to 12 Feb of 2011. As part of their crew application, Max has proposed a launch of GreenCube from a high altitude balloon from the MDRS site. The science justifications for such a flight include the experience of launching such a balloon by an MDRS crew for potential Mars weather observations; a comparison to our Northeast GreenCube2 studies of atmospheric motions to those of this very different environment; a comparison of the sky brightness measurements in the Northeastern woods region to this very different environment. We will consider launching a hybrid of the old and new (GreenCube2 and GreenCube3) designs, and will investigate different ascent and descent rates to keep the balloon range limited to the resources of the (ATV-mobile and space-suited) MDRS crew.

(c)
As in previous proposals, the students remain interested in the possibility of making a version of GreenCube which could be useful for search and rescue or emergency use, such as providing a limited-time cellphone repeater over our (largely un-cell-phone-available) region.

Schedule and specific milestones:
Winter term: Investigate and purchase PV panels; lab testing thereof. MDRS flight if approved. See if sufficient student interest develops in the development of the emergency-GreenCube. Introduce two new WISP students to the project. Continue analysis of GreenCube3 data, and decide on continuation.

Spring term: Develop flight payloads for summer flights, for solar panels, for any GreenCube3 continuation, and/or for the emergency-GreenCube payload..

Summer term: First set of flights, and data analysis thereof.

Fall term: Second set of flights, and data analysis. Discussion of plans for GreenCube5.

Note:
We hope that our sponsors and reviewers at JPL will note that we have requested, at their suggestion in the reviews last year, and received from Dartmouth, a substantial reduction of the university overhead costs. This will significantly increase our direct funds available to the students compared to previous years. Also note that our introductory (first-year) students are often supported by Dartmouth's WISP program.

9. Successor Proposals Only— Describe the accomplishments of the predecessor award.

In last year's SURP proposal, we wrote: *"we request funding to continue building on the success of our GreenCubes and exhibit the Cubes' efficacy in other scientific and engineering investigations. …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."

As described in section 7 above, many of these goals have been met, though because of our funding schedule (February to February), our work is still ongoing. The new direction of GreenCube3 has meant that some changes from the original plan have been made. We are using an imaging CCD rather than a photometer, and the CCD is on the ground-based tracking telescope rather than on the balloon. One of the students, Ben Feintzeig, developed a Matlab-based routine to read in the real-time GPS transmission from the balloon, convert them to pointing directions, and steer the telescope to follow the balloon's trajectory. The balloon mounting structure was changed, and the additional Zigbee radio was incorporated, along with accelerometers. One of our GreenCube2 students, Sean Currey, is back on campus this term and will work on data analysis comparisons of the GPS data from these night-time GreenCube3 flights to the day-time GreenCube2 flights. We launched two balloons together in the summer term, both at night. As stated above, we intend second test flight early this Fall, and a "real" flight later this Fall term.

From my viewpoint as the students' mentor, one of the significant accomplishments so far this year with GreenCube3 was a turnover of responsibilities from the last two graduating students of the original GreenCube program (Phil Bracikowski and Umair Siddiqui), to the present new set. Each student is developing their own role and responsibilities: Amanda is responsible for the onboard instrumentation, Alannah for the radios, Casey the FAA predictions and tracking, Jon the recovery team, William the search efforts, Ben and Max the telescope tracking, Sean the data analysis. I look forward to the progress I expect this group to make this year now that they have come up to speed in taking over the project.

10. Innovative Features— Describe the new and original features of the proposed work.

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 GreenCube4, the students will expand on the existing capabilities of the GreenCube infrastructure, in particular expanding our inhouse knowledge of solar panel use and control. Should the MDRS flight work out, we will have an interesting expansion to a different environment.

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. Please indicate if a student summer internship will be requested if proposal is awarded and how that internship will forward the proposed effort.

N/A: no formal exchanges are planned. However, ***one of the originating students of the GreenCube program (Parker Fagrelius) is now a JPL employee and project manager for the JPL OPALS project, an optical communications project that is part of Phaeton.*** Launch is in two years on ISS. Two of our students, Max Fagin and Sean Currey, participated in NASA internship programs this past year.

13. Significance and Impact of Results on JPL Missions and Programs—Indicate specific missions/programs or types of missions.

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 was the basis of a recent Master's degree student, Phil Bracikowski, who was one of the original GreenCube undergraduates. Presently another graduate student in the group, Lisa Gayetsky (NSF/Career funding), is working on the further development of an ion thermal sensor, the "PIP", which we hope to fly in the lower ionosphere on platforms like the RocketCube; we have submitted a science proposal to NASA/LCAS requesting an auroral sounding rocket flight with 12 instrumented subpayloads.

15. JPL Principal Investigator Signature

Name: Anthony J. Mannucci Signature: A J Mannucci

16. JPL PI Division Manager (or designee) Signature

JFZ

Name: S. LICHTEN Signature:

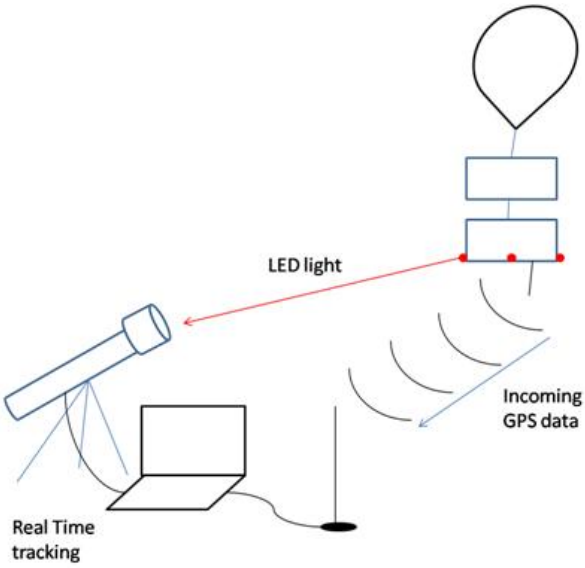
17. University Co-Investigator Signature

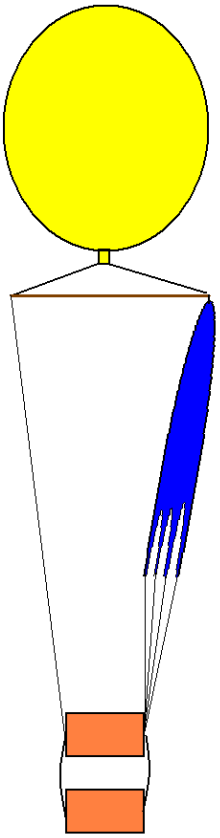
Name: Kristina Lynch Signature:

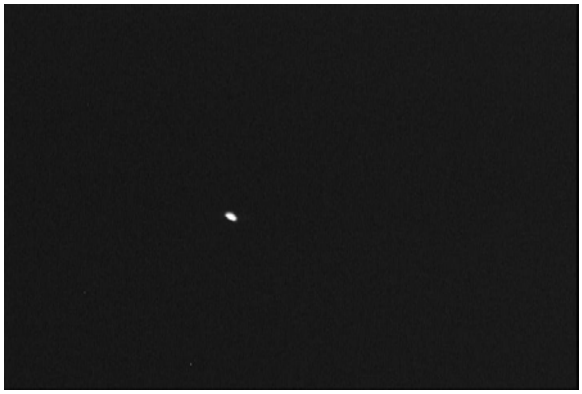
18. University Representative with Signature Authority, if required by university (signature may also be provided instead on a letter attached with university budget backup)

Name: JILL MORTALI, DIRECTOR OSP Signature:

19. Figures, Graphics, Tables, etc.







Some images of GreenCube3 efforts. Top left: the real-time GPS data based telescope tracking of the LED lights on the secondary payload. Top right: the revised suspension system which reduces the payload spin rate. Bottom left: the accelerometer board which has been incorporated into the instrumentation system (from http://www.st.com/stonline/books/pdf/docs/14613.pdf). Bottom right: one of the stills from the CCD image captured by the tracking telescope viewing the LEDs on the flying balloon package during the night flight this summer.

20. SURP Budget Sheet

Category	Dollars
DIRECT COST	
1. **Salaries**— *(Itemize) Only "itemize" the person names or job classifications and the number of hours for each. Show one total $ salary figure for labor.* *Anthony Mannucci. 22 hours*	$1,570
2. **Labor Fringe** — *Employee Benefits*	$780
3. **Cat A Labor**— *(Itemize) Only "itemize" the person names or job classifications and the number of hours for each. Show one total $ figure for labor.* *Itemize names & hours here*	$
4. **Procurements–PO (Equipment, Materials and Supplies)** *(Itemize)* *Itemize here*	$0
5. **Procurement–RSA for University Subcontract(s)** *(Important! See notes #1 and #2 below)* *See breakdown below.*	$21,000
6. **Procurements– PS** *(Itemize)* *Itemize other (non-university) subcontracts*	$0
7. **Services**— *(Itemize) Include all in-house services at JPL* *Itemize here*	$0
8. **Domestic Travel**— *Itemize where and why*	$0
9. **Other**—*(Itemize) Chargebacks*	$110
10. **Total Direct Costs** *(total of dollars 1 through 8)*	$23,460
ALLOCATED DIRECT COSTS (ADC)	
11. **Total Allocated Direct Costs (ADC)** *ADC rates apply to SURP proposals, but not MPS. See your section administrator for help applying the current ADC rates for the various categories of direct costs above.*	$1,540
12. **TOTAL BUDGET REQUEST** (*See Note #3 below.)* *Sum of Item #9 and #10*	$25,000

Note #1: You must attach a budget breakdown from each university partner. There is no page limit and the format is the university's choice. The budget breakdown should be adequate for reviewers to understand labor, procurements, subcontracts, services, travel, and university overhead.

Note #2: Use a "RSA" type of subcontract to send funds to your university partner, except for the following circumstances. If your proposal involves hardware or software deliveries or if government furnished property will be sent to the university, then a RSA subcontract will not be allowed. Under these circumstances, use a "PS" type of subcontract. The ADC rates for these two types of subcontracts are significantly different and it is important to make the distinction in your planning stages.

Note #3: Consider using the new institutional online Price Estimate Generator (PEG) for your budget estimation. Type "PEG" in your browser and follow instructions for requesting access.

21. Budget Details for University Partner(s)

(Replace this page with your collaborator's budget detail. There is no page limit and the format may be of their choosing.)

BUDGET - SUMMARY

AGENCY: JPL (NASA Prime)
TITLE: Dartmouth Greencube 4
Principal Investigator: Kristina Lynch
START DATE: 3/1/2011
END DATE 2/29/2012

		Dartmouth Year 1 3/1/2011 2/29/2012	
PERSONNEL			**TOTAL**
Undergraduate		$12,453	$12,453
FRINGE BENEFITS			
Undergrad 9%		$1,121	$1,121
TOTAL SALARIES		**$13,574**	**$13,574**
TRAVEL		$1,200	$1,200
SUPPLIES		$3,500	$3,500
TOTAL DIRECT COST		**$18,274**	**$18,274**
OVERHEAD	*58.00%*	$2,726	$2,726
(less undergrad support/fringe)	base $4,700		
TOTAL COST		**$21,000**	**$21,000**

Justification:
Travel: Two weeks Alaska or JPL.

F&A Agreement May 25, 2010 Department of Health and Human Services

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