Project: BLAST: A CubeSat Cosmic Ray Observatory
Applicant: Yale Undergraduate Aerospace Association (ex. [anonymized], project leader)

Proposal Abstract

This proposal seeks to launch a cosmic ray detector (CRD) into low Earth orbit. Cosmic rays are a powerful tool to study the early universe and the nature of matter. The project has both a scientific and an educational objective. Our undergraduate team is working to assemble a functioning satellite. The team has and will continue to research the necessary systems and components in order to acquire expertise, skills, and supplies with which to construct the spacecraft. The experimental data we seek to measure will contribute to further scientific understanding of these rays, their genesis, and their substance. We aim to launch a CubeSat into low-Earth orbit in order to conduct measurements of cosmic rays before they enter Earth's atmosphere. Cosmic rays are high-energy streams of particles, mostly of extrasolar origin, which radiate through space. Upon contact with Earth's atmosphere, many of these rays decay into secondary showers consisting of lighter particles. Accordingly, for a given detector, the range of cosmic ray research we can conduct within Earth's atmosphere is limited by the statistical interaction between the atmosphere and the cosmic rays. The identification of the sources of cosmic rays is an active area of research, and the energy distribution of the highest-energy particles at the largest scales has ramifications for cosmology and the theory of particles. We seek to identify and make measurements of the energy of particles in these showers, to contribute to the ongoing collection of data about these rays. Our specific objectives are to build a 2U CubeSat (dim. 20 cm. by 10 cm. by 10 cm.) with fully developed radio communication, power supply, and attitude determination and control systems. Secondary to the cosmic ray detector (CRD), we also plan to launch an Earth camera.

In this specific grant proposal, we seek funding to develop our orientation determination system and radio. This is the particular project, within the multiyear satellite program, for which we are asking for funds. The satellite's payload, the CRD, will be built according to adaptations of open-source designs released by the CosmicWatch project at MIT and the CosmicPi team at CERN. In particular, we intend to use a plastic scintillator together with silicon photomultipliers to detect and identify alpha and beta particles. The satellite's attitude will be controlled by a 3axis magnetorquer, which has already been purchased. Its orientation in space will be defined by a sun sensor, magnetometer, and possibly a GPS unit. The satellite's solar panels will be retracted prior to launch, and the panels will be released by a nichrome burn wire in orbit. We will fabricate our own solar power system from photovoltaic cells. To coordinate and manage these systems, we are authoring and implementing our own control software which will relay sensor data back to ground and transmit instructions up from time to time. Most of the control system will run according to an autonomous algorithm. The construction of the CRD does not require much beyond elementary electrical engineering skills and physics understanding. The projects whose schematics we are using target students at the university level and below and offer clear guidance and advice. Adaptation of these designs to space conditions should not prove too difficult, though this is the main task at hand. Several university and college teams have

launched CubeSats with various payloads already. The subsystems mentioned above are proven, straightforward, and robust. The satellite is a large undertaking. We will take steps to ensure that at every step many eyes are on every part of the architecture, and we will actively consult experienced individuals in academia and industry to make sure each system of the satellite is being constructed properly.

This project is funded by NASA through a grant from the Connecticut Space Grant Consortium, and by the Yale School of Engineering and Applied Sciences. Our organization is also supported by ZipCar.

Relevant budget line items
Support received through this grant will be put towards the purchase of the following parts:

Honeywell Aerospace 3-Axis magnetometer … $1000
Antenna and satellite transceiver … $2000

Note: These are the items which the present proposal seeks to fund. The entire budget for the project at large is also available, if that would be useful.

Reasons for acquisition of these parts (budget narrative)

The magnetometer will provide orientation data for the satellite, relative to the magnetic gradient of the Earth. This will allow us to properly orient the satellite so that the detector face is parallel to the magnetic field lines, which is important for reducing the contribution of trapped radiation, and thereby increasing the quality of our extragalactic ray data. The orientation data is, moreover, important for the experiment itself. We want to map out the distribution of alpha and beta particle radiation, and hence directionality is critical, even if we will only be able to statistically guarantee particulate vectors within a solid angle error. The spacecraft's sun sensor provides an absolute reference frame when in the view of the sun; the magnetic field sensor would provide orientation information even when the satellite is in the dark. This constitutes an essential improvement on dead-reckoning algorithms for the 45 minutes of darkness each orbit. The magnetometer also provides information in sunlight: In this case, the sun sensor provides an absolute correction to the magnetometer. The sun sensor data is more fundamental and reliable, since it is based on the satellite's absolute rotation relative to the solar system, which is easy to measure and invariant in a relative sense. However, since the Earth eclipses the satellite for half its orbit, this data is limited. The magnetometer provides relative rotation as measured against the local magnetic field gradient, but this is a less clearly defined and more variable metric, given underlying vagaries in the field, potential field-dependent measuring difficulties, geomagnetic anomalies, and the electromagnetic reaction of the satellite itself in the low-Earth orbital environment. The two detectors will allow us to pinpoint both in absolute and relative terms the rotational dynamics of the satellite. At release, the spacecraft is likely to be spinning in an unpredictable fashion: We cannot guarantee the disposition of its release in space. That makes these detectors all the more important for our mission.

In the same vein, the onboard radio antenna is a mission-critical capability that we are working to develop. Our payload is a scientific experiment that will require the streaming download of observational data. The spacecraft will, given its dimensions, burn up on reentry, so no hardware data recovery is possible. The transceiver and antenna will also allow manual control instructions to be uploaded in the unlikely event that this is necessary. We are building a ground station this term here in New Haven, and we hope to join an international open-source consortium of satellite ground stations to facilitate the communication of data throughout orbit. A quality antenna on the satellite is a prerequisite for success.

Contact information for funds

[Contact information removed for purposes of anonymity]

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September 27, 2018

Dear Selection Committee,

I am writing to support Keshav Raghavan for a Connecticut Space Grant Consortium student project grant. The grant will support Keshav's work on the CubeSat project this year, which will be focused on researching, building, and launching a CubeSat into low Earth orbit with a cosmic ray detector on board. The project is being performed as part of the Yale Undergraduate Aerospace Association (YUAA), a student organization for which I am the faculty advisor.

The development of this satellite, in addition to the detector's scientific mission, will align closely with NASA's strategic goals of advancing scientific understanding of the universe and cosmic rays, as well as providing an opportunity for hands-on education in science, technology, engineering and mathematics. The project will provide young scientists a unique opportunity to work on aerospace design and technology, hopefully giving them useful experience that will serve them well in their future studies and careers.

Keshav is the team leader for this project, and I am confident he will serve this role well. I have known him through conversations with him as part of my role as YUAA advisor, and he has proven himself to be a competent, responsible, and enthusiastic team member. Early on, Keshav participated actively in the development of the satellite's attitude control and determination systems, where he researched methods of rotation control, actuation, and directional sensing, work which led to the team's acquisition of a magnetorquer and sun sensor this past year. Keshav was an integral part of the team which laid the groundwork for the project this year. The project is seeking a launch opportunity with NASA through the CubeSat Launch Initiative.

In addition to the research and development of the satellite's mechanical control systems, the team has begun the construction of a radio ground station which will allow them to join an international collaboration of stations to communicate with the spacecraft — a significant step for the project. The team has authored sophisticated software to simulate the satellite, given the expected data environment from the sensors, and is working on improving the integration of the several sensors they expect to install on the craft. Keshav and members of his team have also been careful in planning the payload detector and understanding the physics of cosmic rays, reviewing numerous prior designs and particle detection methods.

The overall result from last year was quite important; Keshav and the team learned a huge amount in their work to assemble a functional satellite with a scientific payload. Based on this work and conversations with members of the team, I can speak to Keshav's enthusiasm and professionalism, which led to his being chosen for the role of team leader for the project moving forward. I am confident that the CubeSat project will be successful under Keshav's leadership.

Extra funding from this grant — if approved — would be used to support purchases of critical components for the project.

I enthusiastically support Keshav Raghavan for this student grant and look forward to seeing the project's results. I am sure he will be a great team leader and will devote his time, skills, and enthusiasm towards the the project. As YUAA advisor, I will provide guidance and support as needed. In addition, the project is educational, constructive, and aligns with the key missions of NASA. I am also confident that this leadership opportunity as well as work on the project will have a positive influence on Keshav's future plans as well as those of his team members.

Please contact me if you have any further questions.

Best regards,

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