NASA CONNECTICUT SPACE GRANT CONSORTIUM

Studying Abroad: a CubeSat Cosmic Ray Observatory

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Yale Undergraduate Aerospace Association

Our goals

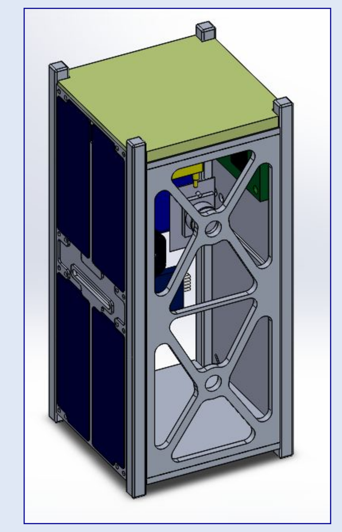
We are working to launch a nanosatellite into space. The spacecraft will carry a cosmic ray detector that will measure the distribution of alpha and beta particle counts and energy levels along its trajectory. The satellite will contribute to our dataset and understanding of the composition and nature of extragalactic cosmic rays around Earth. The project sits at a unique intersection between engineering fields, physics, astronomy, and mathematics. It is remarkable that — just half a century after the first moon landings — even undergraduates can send missions to outer space. As our organization's first satellite project, we're shooting for the moon — and, with any luck, will end up in low-Earth orbit.

Thought process

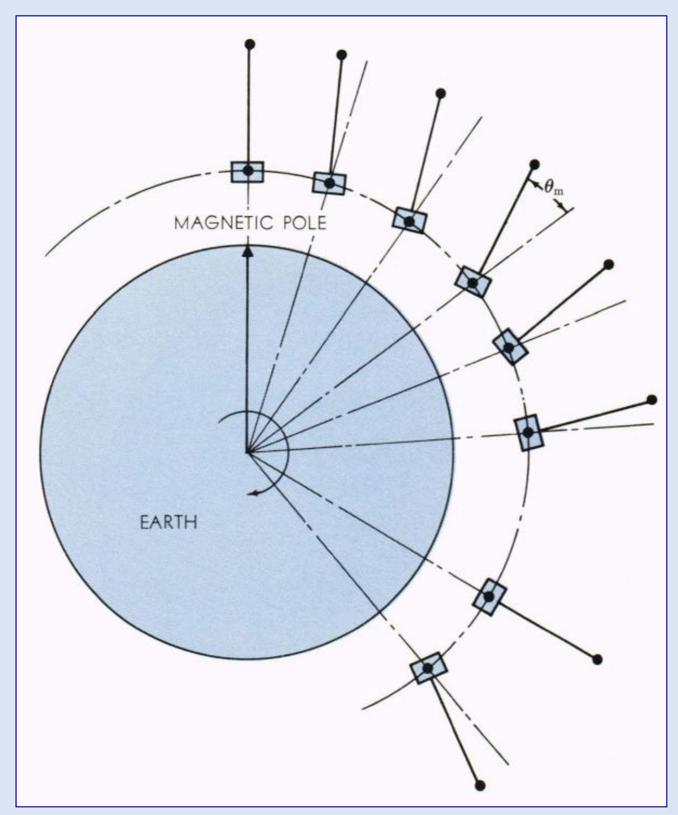
- **What is our scientific mission?** The design of the satellite depends on the specifics of our experiment: the type of particle detector and the specified data. The architecture of the spacecraft's systems follows from these mission requirements. This spacecraft will measure alpha and beta particles, each within a limited energy regime, using a solid-state detector configuration.
- **Is the project feasible and does it merit a launch to space?** As a part of our efforts to specify our payload proposal, we conducted review panels to assess the merit and practicability of the proposed experiment. In these processes, we placed an emphasis on identifying sources of risk, issues of implementation, and assessing the worthiness of this project from the educational and scientific perspectives.
- **How does this satellite get to space?** Our team has put a significant amount of effort this year to move the project closer to launch. This is the fourth year of a satellite project at the YUAA. We entered a proposal in NASA's annual CubeSat Launch Initiative, to secure a launch manifest contract.
- **Any new developments?** We've just begun a working relationship with Yale's Wright Laboratory. This semester we've moved many of our space-ready flight components to a clean room facility there. (*Pictured above*, team members complete introductory training at the lab.) In the future, we hope to develop an engineering test unit at the laboratory, conduct further tests, and final assembly.

Spacecraft systems

In order to run the detector in space and access our data, the satellite must integrate several systems: a radio downlink and ground-station, a battery and power management system, a static solar panel assemblage, attitude determination and control systems. These systems will be coordinated autonomously via the onboard flight computer, which we are programming in-house.

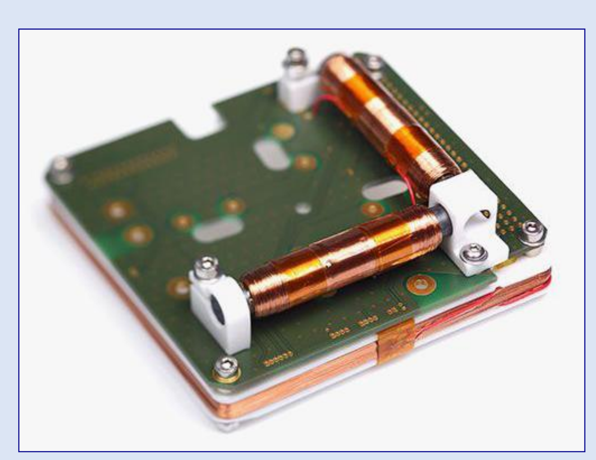


Orientation control



The satellite will be gravity-gradient stabilized. It will primarily use Earth's gravitational field to orient itself. *At left* The initial release dynamics of a passively stabilized satellite, Fig. 3 from R.E. Fischell, "Gravity-Gradient Stabilization of Earth Satellites," APL Technical Digest (1964).

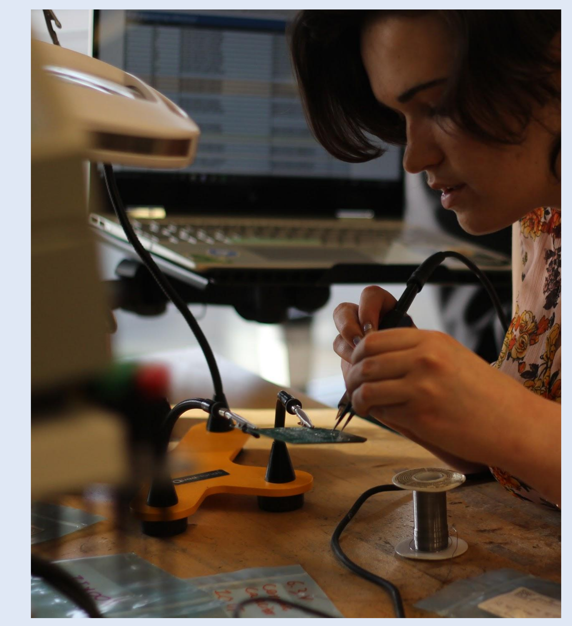
In addition to this passive strategy, the spacecraft will employ a 3-axis magnetorquer to actively damp oscillations and maintain a stable direction vector on the detector face. This combination promotes stability, while maintaining redundancy, simplicity, and energy efficiency. Maintaining the direction of the detector is important, as we hope to record the incidence directions of particles up to a solid angle error. *Below* the Nano Avionics magnetorquer that we have acquired and will use.



Some specifications

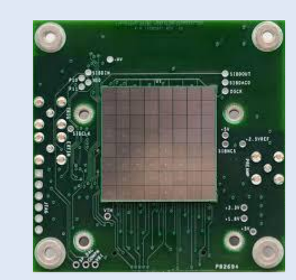
Dimensions constraint: 2 unit (20 cm × 10 cm × 10 cm)
Weight limit: 2.66 kg
Altitude: 400 km, **Inclination:** 51°
Operational length: 120 days

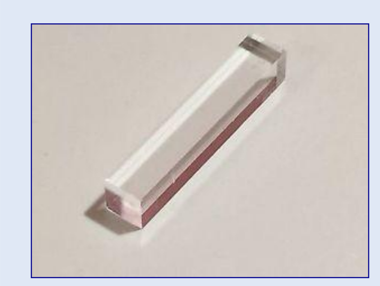
Cosmic ray detector

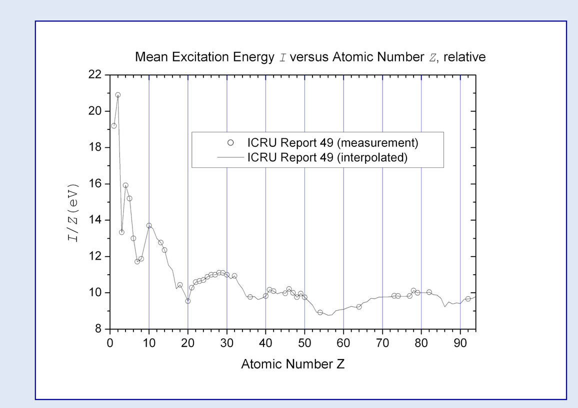


Assembly is under way on a prototype of the cosmic ray detector that we will eventually send to space. *At left*, a team member populates the main PCB board for the detector. The prototype will focus on muon detection at sea level. The detector type is similar, however.

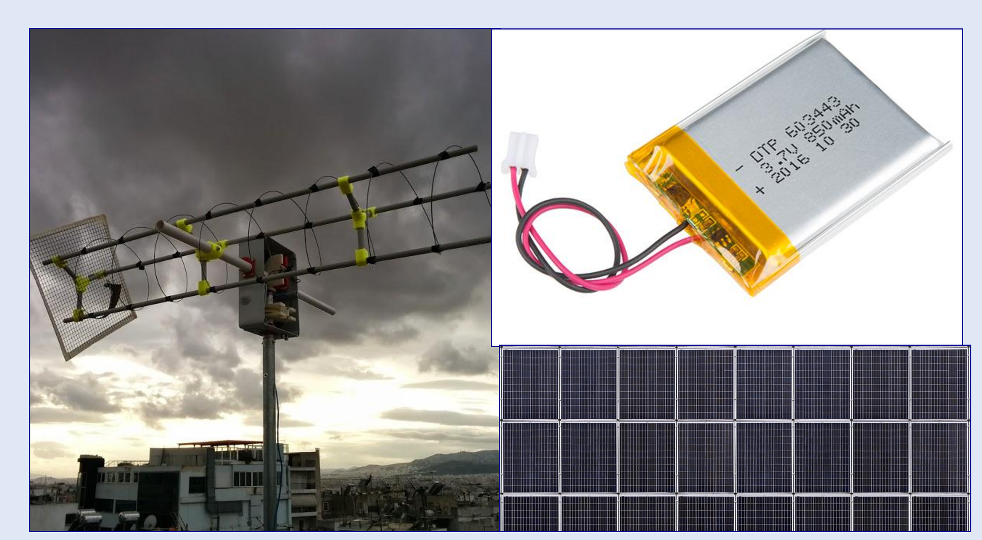
The onboard detector apparatus will consist of stack of plastic scintillator blocks set on top of a silicon photomultiplier (SiPM) chip. When the target particles pass through the scintillating materials, they lose energy. This lost energy is emitted as light, which the SiPM reads in to an electric signal. We can then use a family of techniques known as pulse shape discrimination to identify particle type, and other methods to assess the energy of the particles. A screening cage will limit count.







Radio and power



This year, the team has worked on building a satellite ground station according to open source designs released by the international consortium SatNOGS. *Pictured above left*, what the ground station will look like upon completion. *Top right* A lithium polymer battery. The team has acquired and will run environmental tests on this type of battery for use in space. *Bottom right* Photovoltaic cells. The satellite will feature a static exterior array of solar cells to provide power. The satellite's onboard radio antenna will be deployed via burn wire.

Taking off: progress

Next stop: Space. On Pi Day this year, NASA announced that our project was chosen in the 10th annual CubeSat Launch Initiative selection. Our mission was recommended for launch as an auxiliary payload, and assigned priority 4 out of the 16 missions selected this year. The operations directorate's recommendation is contingent on the negotiation of a launch contract, but marks the first steps towards launch.

Our name Our mission's name, as described in our proposals to NASA, is BLAST: the Bouchet Low-Earth Alpha/beta Space Telescope. The satellite's name honors Edward A. Bouchet, Yale class of 1874, a pioneering American physicist.

Funding secured Thanks to the generosity of all of our donors, acknowledged below, the satellite project has all the support it needs for development and final construction.

Future applications

The data The satellite will collect detailed data on extragalactic alpha and beta radiation in low-Earth orbit, including spatial anisotropies in flux densities, energy averages, and time series. The information will add to our collective astrophysical dataset. Depending on the resolution and energy range we can achieve, the analysis of our data, in conjunction with other cosmic ray measurements, could further scientific understanding, and be useful for observational biasing and foreground effect adjustments.

The concept Immense potential for future uses: networks of sensor CubeSats could address fundamental questions relating to dark matter, and could also host local LEO-communications networks and monitor space debris

Next steps

Although designing and launching a satellite experiment is a difficult process, by dividing the spacecraft into subsystems, and simplifying designs, we have a clear way forward. Going forward, the team will: Complete the ground station, construct an onboard antenna, test the LiFePo batteries that we have acquired, assemble a solar cell system, integrate remaining hardware into the flight control system, implement a stabilization algorithm, test the prototype detector and put together the final payload assembly.

Acknowledgments

Dr. Lawrence Wilen and Dr. Andrew Szymkowiak, for their mentorship and guidance of the team. Wright Laboratory, including Drs. Karsten Heeger, James Nikkel, and Victoria Misenti. The Advanced Exploration Systems division of NASA's HEO directorate, for selecting this mission to launch. And, for their tireless support of this project: the NASA Connecticut Space Grant Consortium, the Yale Science & Engineering Association, Yale SEAS and ZipCar. Thank you to all of our faculty reviewers and team members, past and present. Thank you to everyone who believed in this project.