Educational CubeSat Missions Using Scientific Balloons

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I. The Issue facing Engineering Education

Undergraduate students need more than academic preparation to be successful. Students need to be prepared to work in teams or with people from different disciplines. This experience will cultivate the leadership and interpersonal skills necessary for the students to be effective in the professional environment.

The relatively low cost of CubeSats make it the ideal platform for science and engineering students to apply the knowledge and skills learned in their academic coursework. The primary drawback to student-led CubeSat projects is that it often takes a number of years for a device to be manifested, the students who conceived of and created the CubeSat have long since graduated before it has launched.

A solution to this issue is to fly a CubeSat on a scientific balloon. Putting student built CubeSats on balloon platforms offers a low cost and timely way to build, test, fly, and analyze data from a Cubesat over single year timescales.

II. The Undergraduate Student Instrument Project

Provides opportunities for undergraduate student to develop project management and systems engineering skills for selected U.S. university undergraduate student teams by allowing them to design, build and fly real flight hardware.

UVA's approach to USIP

- Develop a small CubeSat, such as JefferSat, that can measure cosmic ray radiation in the atmosphere using a micro dosimeter. Fly the Cubesat on a scientific balloon to make initial measurements with the intent of flying an enhanced version into Low-Earth Orbit at a later date.
- Allows students to participate in design to flight of a spacecraft in an academic year.
- Provides opportunities for students to work as a team across disciplines to reach a scientific goal.

III. Real World Problems

It is not widely known that every polar flight subjects passengers and crew to the same level of radiation as a chest x-ray. Alarmingly, commercial aircrews receive the largest annual radiation exposure of any occupational group. This high level of exposure is due to cosmic rays (CR) that originate either as galactic cosmic rays or as transient solar energetic particles. The CRs penetrate the magnetosphere and atmosphere, as shown in Figure 1, and result in a radiation dose that increases with altitude.

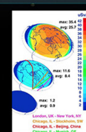
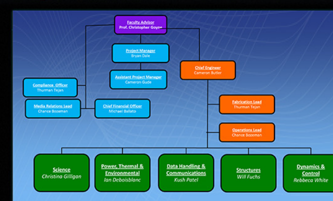


Figure 1 Effective radiation dose at 5, 11, and 15 km altitude, calculated using a NASA model (from Mertens et al. 2010).

NASA's Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model needs to be validated.

The University of Virginia's proposed JefferSat Cosmic Ray Mission (CRM) will involve atmospheric measurements using micro dosimeter devices which can be used to validate and improve NASA's existing models for predicting human exposure to cosmic radiation.

IV. Organizational Chart



V. Payload: Liulin-6SM5

- Device: Spectrometer-Dosimeter
- Functionality: Measures in 256 channels the spectrum of absorbed dose and particle type and energy in the silicon detector
- Weight: 0.092 kg
- Dimension: 110x40x20 mm
- Power: 10.7 RG2 and 9.2 mA RG3 from 8 V DC
- Data transmitted in three ASCII files: Dose(.D05), Spectrum (.S05 and .Y05)—easy to give to NASA as a .csv
- Managed using standard USB port

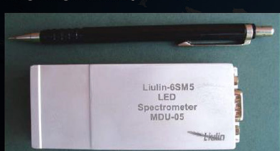


Figure 3 The Liulin-6SM5 Spectrometer-Dosimeter

VI. Jeffersat Satellite Design

- 3U CubeSat
- Uses as much COTS as possible
- Flight Computer is Samsung Galaxy Nexus running Android OS
  - Connects to external GPS, Radio transceiver, & Iridium satellite modem through dedicated USB IOIO device
  - External inputs to IOIO include housekeeping data.
  - Smartphone measures acceleration, barometric pressure and magnetic orientation
  - Internal camera records images during flight.
  - Data and pictures stored on phone internal memory to be recovered after recovery
  - Mission critical data will be transmitted through a radio transceiver to a dedicated ground station
  - Critical data transferred via Iridium satellite modem as a backup

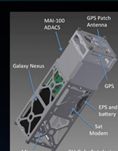


Figure 3 JefferSat 3U CubeSat design (orbital version).

VII. Software and Communication

Jeffersat software is capable of recording data from all the sensors and storing it in the internal MicroSD card. In addition, the software takes pictures using the built in 13 MP auto-focus camera every 5 seconds. The view of the camera will be pointed towards the earth using a 45 degree mirror mechanism when it is in flight.

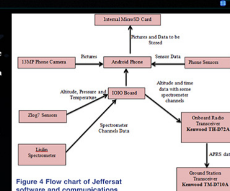


Figure 4 Flow chart of Jeffersat software and communications

VIII. Payload Integration

- Payload requirement < 150-by-150mm square footprint.
- A 90mm circle will be cut into the center of the mounting plate in order for JefferSat to capture photos of the ground.
- JefferSat CRM will be held in place by its four corners using mounting.
- The restraints will be tested for both a 10g vertical and a 5g horizontal shock load with a pendulum impact test rig.

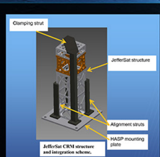


Figure 5 Diagram of payload integration

IX. Thermal Protection

Cryogel Z is an aerogel blanket that is designed to be used in low temperature applications. The low thermal conductivity of 13 to 14 mW / m*K and the low density make 0.13 g cm^-3 make the Cryogel an ideal solution. We decided to use two 10 mm thick blankets to insulate the CubeSat based on preliminary calculations.

Figure 6 Cryogel Z blanket (left). The CubeSat without the insulation (center), and with the insulation (right).

X. Environmental Testing

- The F-7 Thermal Vacuum Chamber (TVAC) at NASA Wallops Flight Facility can be used.
- The TVAC test would validates the thermal analysis. The temperature and pressure inside the chamber mimic the loads in the thermal analysis and ultimately the expected flight environment.
- The power system can be tested to validate that it successfully distributes power to each component. The spectrometer can be tested to confirm the data is collected and stored properly. This environmental test is contingent upon on the cost of the maintenance of the Liulin spectrometer.

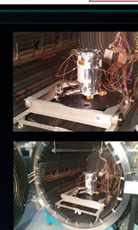


Figure 7 *** CAPTION NEEDED ***

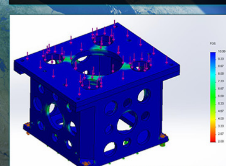


Figure 9 FEA of .75U Structure

FEA Constraints:
- ABS Plastic
- Subjected to a distributed loading of 1000N
- Fixed Geometry at 4 screw holes
- Supported underneath by the 1.5U structure

FEA Constraints:
- Minimum Safety Factor of roughly 5.5 occurs near the edges of holes

Figure 10 Balloon launch from Fort Sumner, New Mexico

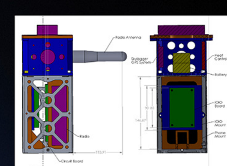


Figure 8 Internal Configuration

- Empty space has been allotted for wiring
- IOIO board mounts onto the phone mount
- Circuit board mounts onto radio mount

XI. Problems Encountered

- There was a failure with the power board. The failure could be either in software or hardware. The hardware failure would be related to issues with the microcontroller or the thermistor while the software failure could stem from incorrect spin code.
- The board was sent back to Bulgaria to be repair, but failed again during integration.
- Flight has been postponed until 9/15

XII. Lessons Learned

- Have spare parts and instruments handy in case of failure. At the very least, have a back-up plan.
- When preparing pre-flight or pre-test procedures, make sure every process mentioned is fully explained and documented. Do not assume that any procedure is understood without elaboration, even if it is assumed to be typical or routine.