UNC Modular Payload Design and Radiation Flux with Altitude

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4/29/2016
Revision D
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1.0 Mission Overview

In this DemoSat mission, our group hoped to achieve a successful launch by having all sensors and heating equipment function correctly throughout the flight. We expect to show that there will be an increase in radiation flux with increased altitude. However, we also expect a decrease in flux above a critical altitude that corresponds with certain changes in the atmosphere. In past flights, UNC has collected similar data supporting this premise. Our mission was to confirm these findings. In addition, we also wished to test the structural stability of our modular payload design.

2.0 Requirements Flow Down

The two main objectives of flight were to develop a modular payload design that can be easily altered and expanded to accommodate future missions, and to use an Arduino to regulate the temperature in the payload while collecting data on the muon flux as a function of altitude.

<table>
<thead>
<tr>
<th>1</th>
<th>Modular Payload</th>
<th>The three components that were required to successfully develop our modular payload design were to have all of the structural pieces of the payload made out of 3D printed ABS plastic for easy manufacture and duplication, have a variety of mounting points to easily alter the design of the payload for future missions, and to be able to easily increase the size of the payload to accommodate future missions. All three of these objectives were successfully accomplished.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>3D Printed</td>
<td>The payload was designed with Google Sketchup and printed with a LulzBot 3D printer.</td>
</tr>
<tr>
<td>1.2</td>
<td>Changeable</td>
<td>The payload has total of 16 different mounting points allowing for a wide variety of different sensor and component configurations.</td>
</tr>
<tr>
<td>1.3</td>
<td>Expandable</td>
<td>The payload has an additional 8 mounting points that are placed in a way to allow for additional structures to be stacked together to create a larger payload.</td>
</tr>
<tr>
<td>2</td>
<td>Arduino Control</td>
<td>The two components that were required to successfully develop our Arduino control system are temperature control and data collection. Both of these objectives were successfully accomplished.</td>
</tr>
<tr>
<td>2.1</td>
<td>Temperature Control</td>
<td>The payload uses a small light weight heating element to keep the temperature inside of the box suitable for the operation of the Arduino, batteries, and sensors.</td>
</tr>
<tr>
<td>2.2</td>
<td>Data Collection</td>
<td>The primary data the was collected was the muon count, in counts per second taken every 5.4 seconds, and the altitude. To collect the muon count, a Sparkfun Geiger counter was used. The altitude was determined used pressure sensor that converted the air pressure into an altitude in feet able sea level.</td>
</tr>
</tbody>
</table>
### 3.0 Design

The following diagrams and schematics show our design to construct the payload and wire the Arduino and sensors. The entire structure was wrapped in foam core board, then fiberglass insulations, and finally nylon reflective sheeting.

**Basic Block Diagram**

```
| Lithium Battery A | Switch | Thermal Heating Pad |

| Lithium Battery B | Switch | Arduino Uno |

| Power Boost and Charger |

| Pressure Sensor |

| SD shield |

| Geiger Counter |

| Temperature Sensor |
```

**Wiring Diagram**
Full 3D Rendering

Structure Exploded Diagram
Arduino Exploded Diagram

Geiger Counter Mount Exploded Diagram
4.0 Management

Our group consisted of two sub-systems. These sub-systems are structural and electrical. Each sub-system had a supervisor that was responsible for all aspects of the completion of their sub-systems tasks. Our management flow chart is below.

Josh Fender is the structural sub-system supervisor.
Veronica Buchanan is the electrical sub-system supervisor.

Each sub-system had their own detailed schedule to follow as well as an overall readiness schedule that was set as a group. The overall readiness schedule is below.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team structure and planning</td>
<td>Nov 1</td>
</tr>
<tr>
<td>Kickoff Telecon</td>
<td>Jan 27</td>
</tr>
<tr>
<td>Preliminary Design Review</td>
<td>Feb 11</td>
</tr>
<tr>
<td>Electronics completed</td>
<td>March 1</td>
</tr>
<tr>
<td>Programming completed</td>
<td>March 1</td>
</tr>
<tr>
<td>Payload structure and probe completed</td>
<td>March 1</td>
</tr>
<tr>
<td>Critical Design Review</td>
<td>March 7-11</td>
</tr>
<tr>
<td>Structural testing completed</td>
<td>March 15</td>
</tr>
<tr>
<td>Electrical testing completed</td>
<td>March 15</td>
</tr>
<tr>
<td>Programming testing completed</td>
<td>March 15</td>
</tr>
<tr>
<td>Full integration and systems readiness check</td>
<td>March 31</td>
</tr>
<tr>
<td>Launch Readiness Review</td>
<td>April 4-8</td>
</tr>
<tr>
<td>LAUNCH!</td>
<td>April 9</td>
</tr>
<tr>
<td>Final Reports Due</td>
<td>April 29</td>
</tr>
</tbody>
</table>
5.0 Budget

Our overall monetary budget was $500.00 and we only spent $302.40. Our parts list and expenditures are below.

- Polymer Lithium Ion Batteries 2000mAh (4) @ $12.95 each (SparkFun)
- PowerBoost 1000 Charger (1) @ $19.95 each (AdaFruit)
- Barometric Pressure/Altitude Sensor (2) @ $9.95 each (AdaFruit)
- Geiger Counter (1) @ $149.95 each (SparkFun)
- Sparkfun 5V Step-up breakout (1) @ $5.95 each (SparkFun)
- SparkFun RedBoard (1) @ $19.95 each (SparkFun)
- Arduino Uno R3 (1) @ $24.95 each (SparkFun)
- Temperature Sensor- Waterproof (1) @ $9.95 each (SparkFun)

Total: $302.40

Our overall mass budget was:

- Box frame, supports and Arduino components: 0.300 kg
- Geiger counter: 0.262 kg
- Heating pads: 0.018 kg
- Batteries: 0.148 kg
- Flight tube and outer insulation: 0.300 kg

Total: 1.028 kg

6.0 Test Plan and Results

In order to ensure that the payload was functioning properly prior to the launch date, it was necessary that the structural design and electronic components/programming were tested. The main purpose of the structural design was to prevent any damage done to the electronic components. With this in mind, it was not necessary for the structure to stay intact post impact. The internal structure was 3D printed using ABS material which provided enough rigidity to keep the electronic components intact. The external structure used foam core to help maintain overall structural integrity and Mylar to help maintain a relatively warm environment so that the electronic components maintained proper operating temperatures during the flight. A drop test was conducted to simulate the impact the payload would experience once it returned to the ground.
The electronic components were researched prior to installment so that we were sure of the components’ ability to function at the extreme conditions that the payload would experience during the flight. Data acquisition relied on the programming. The testing done on the electronic components required a lot of programming/troubleshooting and running of the electronics to test their ability to gather data. We found that during testing, the program displayed a lot of errors. After additional testing, we came to the conclusion that a specific electronic component was damaged. Once we replaced the component, the electronics began functioning correctly.

7.0 Expected Results

We expect to obtain data points of temperature inside the payload, altitude (i.e. position of payload relative to the surface of the Earth), and muon counts every 5.4 seconds. We expect to find a relation between altitude and muon counts that mimic the data gathered from prior launches.

8.0 Launch and Recovery

Pre-Launch

The launch of the Demosat balloon for the spring semester of the 2016 school year occurred on the Ninth of April, 2016. That morning all members of the team participating in the launch met at Eaton Middle School in Eaton Colorado. The launch of our project was carried out by Alex Briggs, a member of the electronics team. Prior to the launch we insured that all electronics are activated and working properly. The actual launch of the balloon occurred at approximately 0700 hours, and from there the team prepared for the chase.

Post-Launch

After the 0700 launch, the recovery team assembled in a convoy with mobile balloon tracking stations in some of the vehicles. With the guidance from the tracking information the recovery team followed the balloons path until it landed on the private property of a farm that was due East of Eaton, Colorado. Shortly after landing we acquired permission from the land owner to retrieve our project. Upon recovery the team inspected the payload for physical damage, and tested the functionality of the electronics. With all systems passing the initial tests upon landing, the recovery team returned to the University of Northern Colorado for closer examination and testing.
9.0 Results, Analysis, and Conclusions

Our results displayed reasonable data collected throughout the flight. This suggested that all sensors and heating components functioned properly. We predicted an increase in muon counts per minute as the payload ascends up to a certain point where particle collision is not as common. Our data showed an increase in muon counts detected; however, the payload did not reach a high enough altitude where we expected the muon counts to start decreasing. Therefore, our data did not exactly mirror past DemoSat experiments.

According to data collected from the altitude sensor and Geiger Counter, which is presented in the graph below, there was an increase in radiation flux with respect to altitude. The muon counts per minute increased at a linear rate until the payload reached about 50,000 feet. At this point, the muon counts seemed to stabilize. At approximately 55,000 feet the payload began to descend. The data collected during the descent also match our expectations that the muon count is directly related to the altitude.
10.0 Ready for Flight

Our payload worked well, so we can be ready for flight tomorrow. However, if we wanted to fully test the modular design, we would want to create another research idea and fly the components necessary for that research.

11.0 Conclusions and Lessons Learned

Throughout this project, our team has learned how to build a payload. The structural design team advanced their knowledge on 3D design and printing of individual components for the payload to minimize volume and mass. The electronics team was able to gain experience with creating circuits and learning how to program an Arduino microprocessor. If we had a chance to participate in another launch, we would advance this project by adding more and/or different types of sensors, instead of reproducing previous data. In the future, we hope to conduct an experiment that has not yet been done by UNC.

12.0 Message to Next Year

Again, enjoy yourself. The faculty at the University of Northern Colorado and staff at Colorado Space Grant Consortium have worked hard to provide you with this amazing opportunity. Make sure you earn it.