The Gamma Gang

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1.0 Mission Statement, Requirements, and Expected Results
Our mission is to measure the polarization of gamma rays. To complete our mission we need to record a statistically significant number of samples from our 12 gamma detectors. We hope to couple those samples with readings from our IMU to improve our results by accounting for the rotation of the rocket itself. We also plan to record video and ambient light samples from the optical port, which will be used to verify the IMU data.

We expect to see unpolarized background levels for the vast majority of the flight. If we are lucky enough to be flying during a gamma event, we hope to see elevated readings from opposing gamma detectors. Due to the directional nature of our experiment and the rotation of the rocket, we expect those elevated readings would appear on multiple pairs of sensors at different times. Gamma events are rare and don’t last long, so we will need some luck to detect one.

A successful mission will mean we recorded several hundred thousand samples using the majority of our gamma detectors. IMU and camera data will greatly enhance our results, but are not strictly necessary for a successful mission.

2.0 Final Payload Design
Our final design combines 12 directional gamma detectors, a photoresistor and camera pointed out the optical port, two raspberry pi 3 computers, and several supporting custom printed circuit boards connected to 4 batteries.

The majority of the canister was reserved for our 12 detectors, which are arranged in a dodecahedron around a central block of scattering material. The experiment relies on Compton scattering to reflect gamma particles from the central block towards our detectors. A gamma event will scatter a very high number of particles towards our sensors, allowing us to distinguish between background noise and polarized radiation.

Plates above and below the detectors hold our batteries, PCB’s, raspberry pi computers and other supporting electronics.
This is a recent picture of our payload. We made some late adjustments to distribute our electronics across both the top and bottom layers, but otherwise it stayed very close to the original design. Wire management was a surprisingly significant challenge with so many sensors and components.

The mechanical portion was crafted from blocks and plates of aluminum, which gave us a lot of control over the final result. We were able to organize the detectors in the shape of a dodecahedron for optimal results, while maintaining an incredibly strong structural frame.

Here are a few of our 12 gamma detectors. Each one includes a directional sensor and supporting electronics on a custom PCB. These have been the most challenging portion of the experiment, because the sensors need to detect the right range of energies with an acceptable signal-to-noise ratio. Each sensor puts out a range of voltage which can be read by the raspberry pi.

Detailed Mass Budget:

Oregon State University and Linn-Benton Community College
RockSat-C 2016
<table>
<thead>
<tr>
<th>Part Name</th>
<th>Qty</th>
<th>Weight (lb)</th>
<th>Net (lb)</th>
</tr>
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<tbody>
<tr>
<td>Sensor Column</td>
<td>10</td>
<td>0.13285</td>
<td>1.3285</td>
</tr>
<tr>
<td>Power Board</td>
<td>1</td>
<td>0.1276476</td>
<td>0.1276476</td>
</tr>
<tr>
<td>Battery</td>
<td>4</td>
<td>0.09</td>
<td>0.36</td>
</tr>
<tr>
<td>Raspberry Pi 3</td>
<td>2</td>
<td>0.0507063</td>
<td>0.1014126</td>
</tr>
<tr>
<td>Angled Block</td>
<td>10</td>
<td>0.044</td>
<td>0.44</td>
</tr>
<tr>
<td>Sensor Cap</td>
<td>12</td>
<td>0.026</td>
<td>0.312</td>
</tr>
<tr>
<td>Battery Holder</td>
<td>4</td>
<td>0.0749572</td>
<td>0.2998288</td>
</tr>
<tr>
<td>Canister</td>
<td>1</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Scattering Housing</td>
<td>2</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>Central Pillar W/ Hole</td>
<td>4</td>
<td>0.13463</td>
<td>0.53852</td>
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<tr>
<td>Support Pillars</td>
<td>10</td>
<td>0.05824</td>
<td>0.5824</td>
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<tr>
<td>Intermediary Plate</td>
<td>2</td>
<td>1.34657</td>
<td>2.69314</td>
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<tr>
<td>Spacer</td>
<td>48</td>
<td>0.0011</td>
<td>0.0528</td>
</tr>
<tr>
<td>End Plate</td>
<td>2</td>
<td>1.36917</td>
<td>2.73834</td>
</tr>
<tr>
<td>1/4-20 x 3/4</td>
<td>20</td>
<td>0.0141</td>
<td>0.282</td>
</tr>
<tr>
<td>1/4-20 x 1/2</td>
<td>30</td>
<td>0.01153</td>
<td>0.3459</td>
</tr>
<tr>
<td>#8-32 x 1/2</td>
<td>16</td>
<td>0.0043</td>
<td>0.0688</td>
</tr>
<tr>
<td>#4-48 x 1</td>
<td>48</td>
<td>0.0029</td>
<td>0.1392</td>
</tr>
<tr>
<td>1/4-20 x 1/2 LPH</td>
<td>10</td>
<td>0.0086</td>
<td>0.086</td>
</tr>
<tr>
<td>Scintillating Material</td>
<td>12</td>
<td>0.00092</td>
<td>0.01104</td>
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<tr>
<td>Scattering Block</td>
<td>1</td>
<td>0.298</td>
<td>0.298</td>
</tr>
<tr>
<td>Mass Ballast</td>
<td>10</td>
<td>.3113</td>
<td>3.113</td>
</tr>
</tbody>
</table>

Total 20.00
3.0 Testing Results

Testing has been a major challenge for us, and something we are still struggling with.

We encountered many delays while developing our sensors, and we fell behind schedule. Two weeks before launch we still have several incomplete or untested systems.

Mechanical status:
- FEA, weight, simulated C.G, canister fit, and vibration(without electronics).
- All hardware including electronics fits securely inside the payload.
- Adjusted weight to 20 lbs, allowances made for final electrical hardware changes.

Software status:
- Orientation Software (IMU), written in Python.
- Creates a new log file using the current date and time.
- Records the current date and time as the first line of the log.
- Each additional line of the log contains:
  - Timestamp in milliseconds
  - Magnetometer values (x,y,z)
  - Accelerometer values (x,y,z)
  - Gyroscope values (x,y,z)
- Shuts down after 30 minutes.
- Camera and light sensor have yet to be included in the software.
- Needs more testing to analyze results after the flight.

Detector Software, written in C++
- Creates a new log file using the current date and time.
- Records the current date and time as the first line of the log.
- Each additional line of the log contains:
  - Timestamp in milliseconds
  - One 10-bit value (0-1024) for each of the 12 gamma detectors.
- Shuts down after 30 minutes.
- Average loop time of ~1 ms.
- Needs more testing using detector hardware.

Electrical status:
- Gamma detectors built and tested using lab equipment, but not radiation.
- Power PCB previously passed tests, but now failing them. Redesigning.
- Connecting PCB could not be tested until recently, now failing. Redesigning.
Full Mission Simulation Results status:
As of June 6th, we are still struggling to get a full systems test completed.

Our current problem is that we have insufficient current to power all of our electronics, causing the computers to reboot endlessly. We believe we have found a solution but need more time to implement and test it.

Another new problem is that we are seeing inconsistent results from our analog to digital converters, which read the voltage from the detectors and feed that digital signal into the raspberry pi. We believe this problem stems from using an unfiltered source for the baseline, but again we need time to implement and test a solution.

This week we are all taking finals and attempting to hold it all together. We have build sessions in the evenings to try to resolve these problems because we know that we are very close to running out of time.

We have a test scheduled in the radiation center for June 9th, and we hope to have our electrical problems resolved by then.

If we are unable to get our detectors working, our payload should still be capable of recording some interesting data from the IMU, camera, and photoresistor systems. However, we would fail our primary mission of measuring gamma radiation.

A. Integrated Subsystem Testing Results

As of present day we have tested the following subsystem integrations:

- Mechanical-Electrical Vibration testing. With fully assembled electronics we have conducted standard vibration tests. (Low amplitude, High frequency) to confirm that all mounting is secure and components will remain in place during flight. See FMSR.
- Mechanical-Electrical Insulation testing. Fully assembled, there is no voltage on the canister and all components properly insulated. See FMSR.
- Mechanical-Electrical Fit testing. All components including camera are mounted appropriately in their correct orientation without issue. Weight has been adjusted accordingly to retain 20 lb load.
- Electric-Software Orientation testing. Acc/Gyro/Mag sensors have been tested and incorporated. See FMSR.
- Electric-Software Python Code testing. Python code has been written and can write to all needed storage. See FMSR.
Incomplete or unsuccessful subsystem integrations are as follows:

- Sensor Radiation tests. While our sensors detect radiation in a small scale tabletop environment, section 3.0 details our current issues and problems with this subsystem. We will be unable to test the payload’s response to gamma radiation prior to launch.

- On 6/9/16 we traced our current electrical problem to a drop in voltage between our 5v regulator and the raspberry pi’s, which is causing them to restart uncontrollably. We will attempt to fix the problem by rerouting power to a new pcb very close to the pi’s. Between the combinaton of separating voltage for sensor and each pis, and the reduced distance, we hope this will solve our problem and should have new test results by 6/10/16.

- We will be shipping the bulk of the payload on 6/10/16, but we will keep some of the electronics including our computers, pcb’s, and spare sensors. These components will allow us to spend a few extra days of testing and will be brought to Virginia in our carry on luggage. We aren’t happy about this solution, but feel it’s our best chance.

B. Full Mission Simulation Results

We have attempted one full mission simulation with all electronics, sensors, and power mounted to the payload frame without exposure to radiation. This simulation was unsuccessful as we encountered problems with our power and ADC PCB’s.

The problem was initially traced to low current causing the computers to endlessly restart, but when we attempted to use an additional power supply for the computers, we discovered our sensors were also fluctuating in what appeared to be a sin wave. We suspect the interference may be caused by sharing a 5v source between the pi and ADC reference may be causing the problem.

We are attempting to solve both of these problems by creating a new pcb that will provide more current to the pi’s, and a filtered reference source to the ADC’s.
### 4.0 Launch Readiness

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can</td>
<td>-0.5” in Z is furthest from center</td>
</tr>
<tr>
<td>Contained in can</td>
<td>All Components 0.25” from canister wall</td>
</tr>
<tr>
<td>Connected to can by 4 or 5 bulkheads on top and bottom only</td>
<td>Using % on each bulkhead. Center hole excluded.</td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td>Weighed - Yes</td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td>N/A</td>
</tr>
<tr>
<td>No voltage on the can</td>
<td>Tested - Yes</td>
</tr>
<tr>
<td>Activation wires at least 4 ft</td>
<td>Incomplete</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>Incomplete</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>Tests indicate &lt;800 mA on startup.</td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td>Not using</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Lithium-Manganese Dioxide</td>
</tr>
</tbody>
</table>

We have not yet created the early activation wires, but do not expect a problem there. We have simply been busy with other mission-critical aspects of the payload. We should have created these by now, but we haven’t.
B. Integration Plan and Procedure:

To Access Electronics Layers:
1. Remove Canister Top by first unbolting 8-32 x 3/8” screws from around the canister. Flip canister and remove bottom 4 bulkhead bolts. Flip and remove top 4.
2. Set Top aside and pull entire payload frame from out of the canister.
3. Remove Top or Bottom Electronics Plate by unbolting the 5 Black Low Profile Bolts connected to the column pillars. Use Vice Grip Pliers to hold the Column if it spins indefinitely.
4. Disconnect Sensor/Power connections to PCB and remove Top/Bottom Plate. Conduct service as needed.

To Access Sensors:
1. Follow steps to access Electronics Layers, detailed above.
2. Leave column pillars attached to Central Plates, unbolt the four 8-32 bolts located near the center of the disk oriented in a square. these are connected to the 4 central pillars that run between the two central plates. Unbolt and remove central plate.
3. Flip plate over such that the column pillars face down, and Sensor array points upwards. Careful of wire connections.
4. Remove 4-48 bolts located at the top of each sensor pillar on the sensor cap. Be aware that Spacers are located on these bolts and they might fall.
5. Removing the Sensor Cap exposes each individual sensor and allows it to be removed as needed. To remove a sensor-cut wire (Cut the wire at a length where it has passed through the hole on the central plate at the base of each pillar. It is not possible to remove a sensor without replacing it’s wire connection.)

Action Items:
1. Ensure the payload can successfully power up and record results from the sensors!
2. Connect and test the camera. (rapidly becoming a stretch goal)
3. Connect and test the photoresistor. (rapidly becoming a stretch goal)
5.0 Conclusions
This project has been an adventure. Clearly, we underestimated the difficulty in designing our own sensors, and our mission is now in grave danger because of that mistake. We believe we set realistic milestones but did not make emergency adjustments as we repeatedly failed to meet our testing deadlines.

We will continue working until launch, but the fact that we still have work to do means that we made significant mistakes along the way. At this point in the project we should be testing edge cases, not our primary components.

Going forward, this project may end up as a lesson in humility as well as time management. None of us want to fail, but we may learn just that.