Investigating the Impact of a Solar Eclipse on Atmospheric Radiation

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ABSTRACT

Muons are created when high energy cosmic particles like protons collide with atmospheric molecules, such as diatomic oxygen or nitrogen. These collisions create new molecules and decay products such as muons. It is known that there is a relationship between muon production and altitude.

For this project, we have developed a method for the detection of cosmic ray muons as a function of altitude. The detector is part of a self-contained autonomous payload that is carried up to altitude aboard a weather balloon. The payload contains a coincidence circuit made of three Geiger-Müller tubes that make up the actual muon detector apparatus. This system, along with various other sensors including internal and external temperature sensors and an altimeter, are controlled by an onboard Arduino Mega microcontroller.

The experiment was launched during the total solar eclipse on 21 August, 2017.

EXPECTED DATA

The payload will experience a change in radiation flux as it ascends. We expect the muon count to increase with altitude until 10-12 miles. At altitudes over 12 miles, we expect the count to decrease with altitude (Fig. 1). This dip in muon count is known as the Pfotzer Curve. The curve is due to less atmosphere being present, and thus fewer radiation scattering events taking place. A portion of the cosmic rays that generate the showers of muons originate from our Sun. During the eclipse we expect to observe a lower overall count rate during the actual eclipse caused by the rays from the Sun being blocked by the moon.

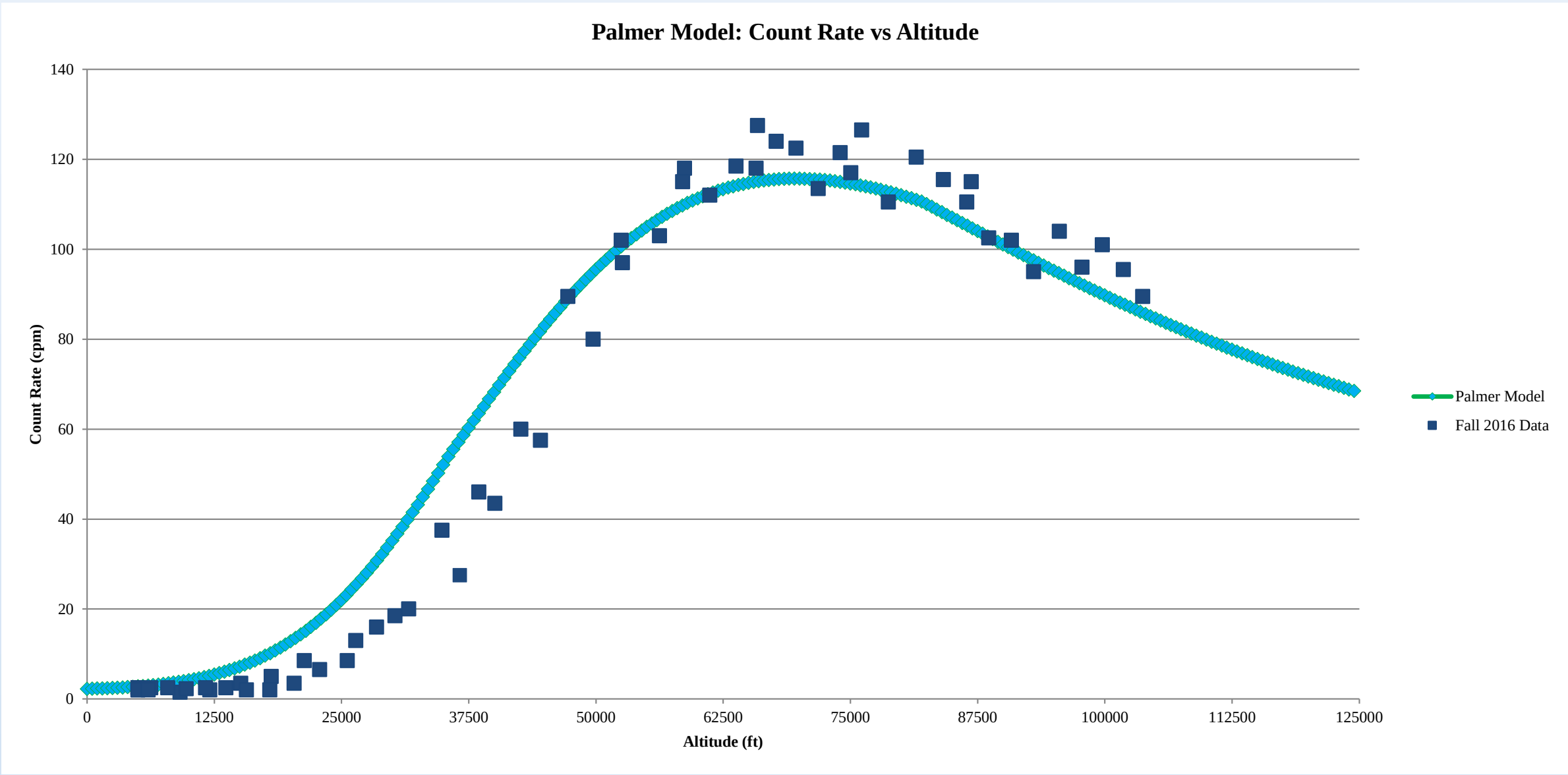

Figure 1. Muon count versus altitude. The blue data points were collected during a balloon flight in the fall of 2016. The green line is a mathematical model developed by Dr. Michael Palmer from West Virginia University and adapted to fit our collection surface.

ACKNOWLEDGMENTS

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IDENTIFICATION OF MUONS

The current experiment is built upon previous attempts to measure muon flux as it varies with altitude using Geiger-Müller tubes. A downfall of the use of a single Geiger-Müller tube is that any charged particle will trigger a "count" in the device. In the experiment, three tubes were wired to a coincidence circuit to help identify just the muons that passed through the payload. Given their high energy (relative to other forms of cosmic radiation), there is a nominal probability will not be positively identified by a single device. Only when at least two of the tubes were triggered "simultaneously" would the count be increased. Stacking the Geiger-Müller tubes vertically allowed us to determine and control the direction from which particles would be detected. To increase the detection angle, the Geiger-Müller tubes were stacked and spaced (Fig. 2).

To reduce uncertainty further, thin sheets of lead encased each tube. The lead acted as a filtering agent by attenuating the radiation caused by particles other than muons. The muon has much higher energy than other particles and is not as easily absorbed or deflected by lead.

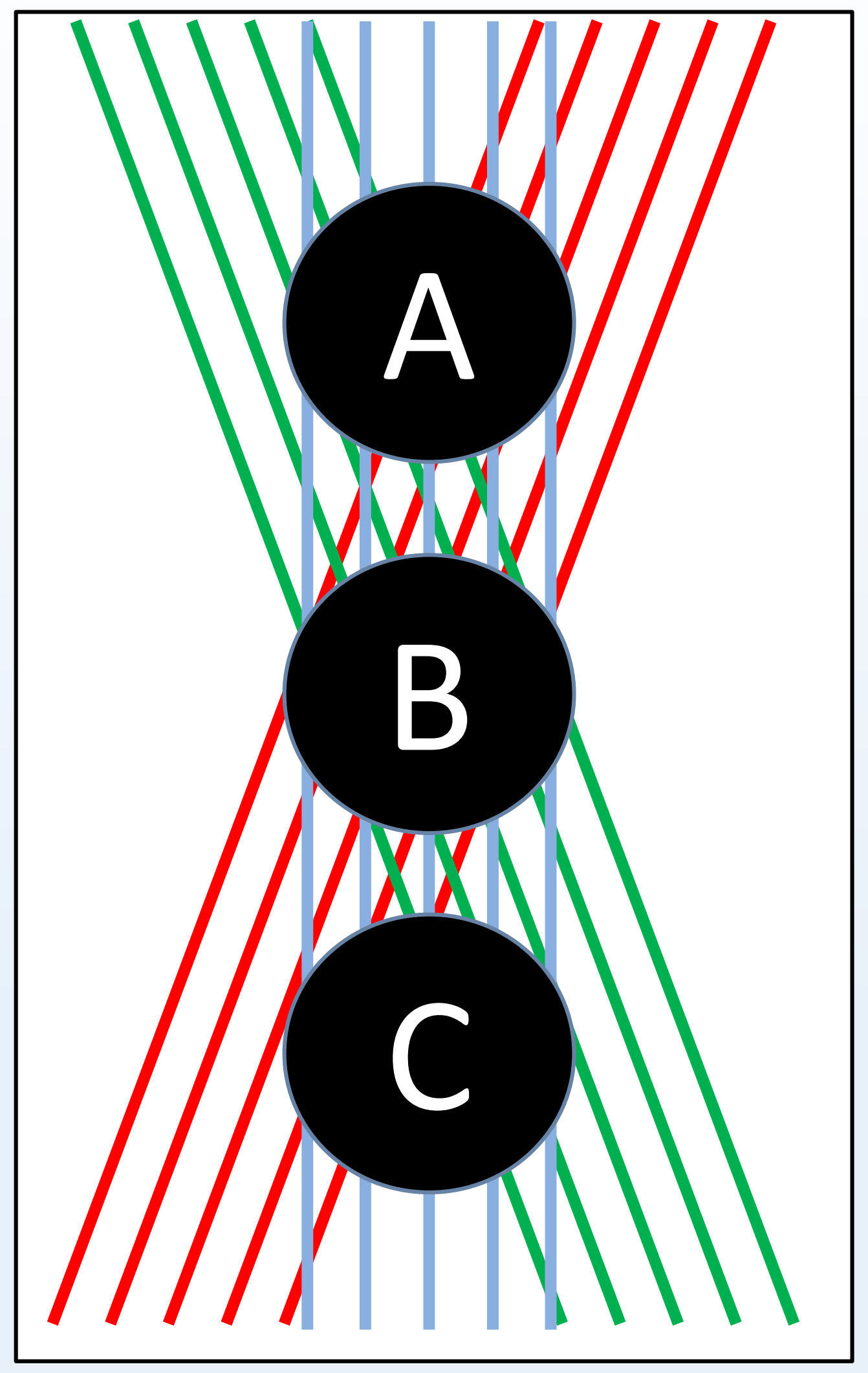


Figure 2. The orientation of detectors A, B, and C. The lines indicate the detection window. Only when a particle passes through at least two of the detectors does it trigger a muon count.

RESULTS

The data followed the general trend line found in the Pfotzer curve (Fig. 3), as expected and predicted by the Palmer model. There seemed to be little to no noticeable effect due to line-of-sight solar blockage on the detection of muons. This suggests that the primary sources of muon production in the atmosphere are indeed due to extrasolar cosmic rays. However, the trends in data were different enough from previous flights to warrant an additional flight to collect more background data.

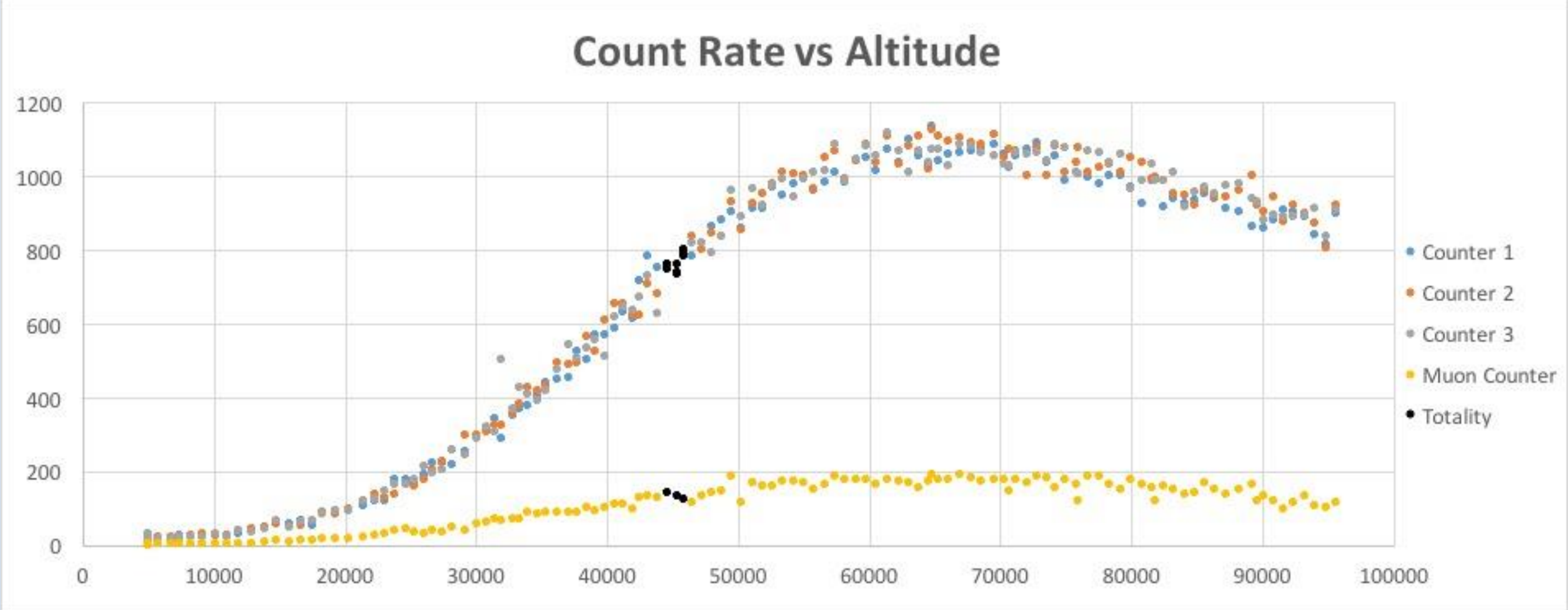
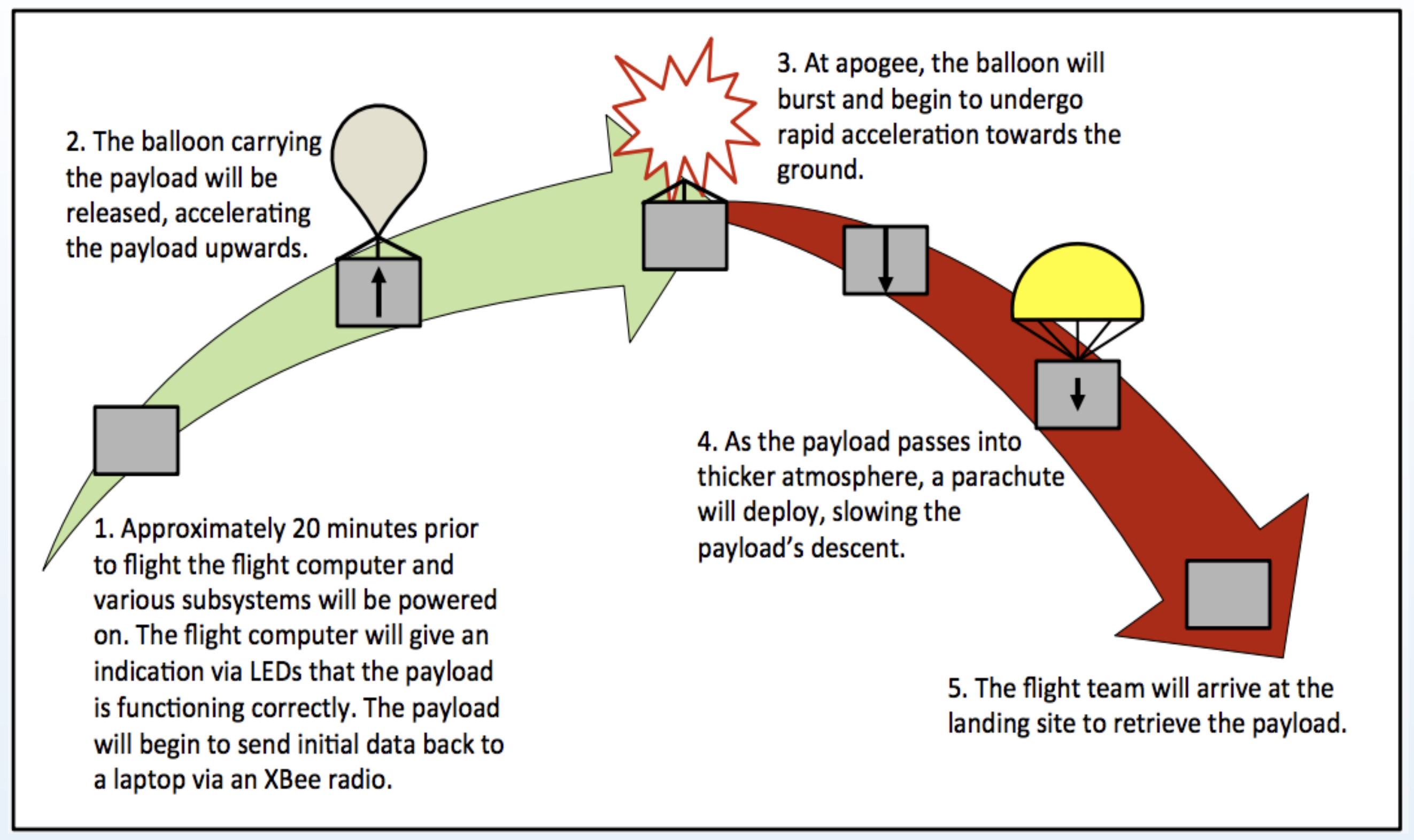


Figure 3. The raw results collected from the payload during the total solar eclipse. The blue, orange, and gray dots correspond to positive independent detections made by counters 1, 2, and 3, respectively. The yellow dots represent a positive coincidence count. The black dots represent detections made while the payload was experiencing totality.

CONCEPT OF OPERATION



1. Approximately 20 minutes prior to flight the flight computer and various subsystems will be powered on. The flight computer will give an indication via LEDs that the payload is functioning correctly. The payload will begin to send initial data back to a laptop via an XBee radio.

2. The balloon carrying the payload will be released, accelerating the payload upwards.

3. At apogee, the balloon will burst and begin to undergo rapid acceleration towards the ground.

4. As the payload passes into thicker atmosphere, a parachute will deploy, slowing the payload's descent.

5. The flight team will arrive at the landing site to retrieve the payload.

Figure 4. Overview of the expected flight plan

TESTING

To ensure our payload's readiness, we test the electronic and structural components. The payload will reach an altitude of between 15 and 20 miles and must be able to endure harsh conditions including:

- *Temperatures ranging from -80°C to 25°C.*
- *Accelerations up to 8 G's.*

Electronics Tests

- All data collected during this period are compared with known values to ensure each sensor's accuracy.
- All sensors and the program code are run for a duration of 4 hours (approximately the length of the launch).

Physical Tests

- We drop the payload from a height of approximately 40 feet to test payload survivability during a hard landing.
- The payload is whip tested to determine payload survivability during large accelerations.
- The payload is cold tested to simulate payload functionality in a low-temperature environment, such as found in the upper atmosphere

POST FLIGHT

After recovery of the payload, it was inspected for damage and the device's stored data were retrieved. The data were then analyzed by comparing the new data to the results of past experiments as well as the Palmer model adapted to the parameters associated with this flight.