Cosmic Ray Measurement and Analysis

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The High Altitude Research Platform (HARP) will utilize a suite of instruments to measure cosmic rays up to an altitude of 35 km. The first of these, the Aware Electronics Model RM-60 Pro Geiger Counter, has been tested in multiple Taylor University balloon launches. Its primary purpose is to determine the amount of cosmic radiation (ions, gamma rays, subatomic particles) at different altitudes. The most recent daytime launch took place on March 9, 2013 and gathered count rate data from an altitude of 0 to 20 km. The count rate from 0 to 4000 meters was unexpectedly constant at an average of approximately 0.2 cps (counts per second). As the balloon flew past 4000 m, the count rate increased until it reached a maximum of approximately 14 cps at a height of about 19 km. The second instrument that was flown was the Vernier Radiation Monitor. It has similar dimensions to the aforementioned Geiger counter (cylinder of diameter 15.20 mm, height 40.78 mm, and volume 7400 mm^3) yet is more compact. It will be shielded with lead to define the field-of-view. The Vernier sensor will be mounted on the outside of the launch pod so that it will measure the count rate without obstruction. Signal processing, including the Boxcar Averaging Method, has been employed in the analysis of the current data. The second launch took place at night on April 22, 2013 and reached altitudes greater than 30 km. On June 5, 2013, a third daytime launch collected data using the Vernier sensor. The results of the daytime and nighttime launches have been compared and synthesized to further investigate cosmic radiation. This diverse number of instruments allowed us to examine cosmic rays from multiple different angles and achieve significant new results.

I. Introduction

GEIGER counters are very practical instuments to measure cosmic rays throughout the atmosphere. Whenever an energetic particle passes through the tube, the gas within is ionized and a count is recorded. Utilizing the Taylor University High Altitude Research Platform (HARP), we launched multiple Geiger counters (GC) using high altitude latex balloons. Originally, we used the AWARE Electronics RM-60 Pro Geiger counter due to its tough exterior. Also, it has been tested and proven useful in many previous flights. This Geiger counter would have to endure extreme turbulence as a result of surpassing an altitude of 30 km. Because of this, a base was designed in SolidWorks and printed on a 3D printer to steady and protect the Geiger counter while also protecting the other equipment.

In addition to the AWARE Electonics RM-60 Pro Geiger counter, a Vernier Radiation Monitor was also flown with the intent of comparing the count rates of each. The Vernier Monitor was wrapped with lead shielding to define the field of view and limit the detection of particles to those entering from above.

Incoming cosmic rays from our sun and outside our solar system are passing through Earth's atmosphere all the time. When a particle enters the atmosphere, it collides with other molecules and creates a cascade of lighter particles. This scattering causes an increase in particle count rates because one particle breaks up into multiple smaller ones, most of which can be detected by the Geiger counters. As these smaller, secondary particles continue

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through the atmosphere, only a few of them, such as muons, reach Earth's surface. A plot of this phenomena is shown in Fig. 1. The maximum due to the cascade of particles is known as the Pfotzer maximum.

Our Geiger counters have detected this Pfotzer maximum on each flight. This allows us to compare the particle count during the day and night using the RM-60 without lead shielding and the Vernier with shielding.

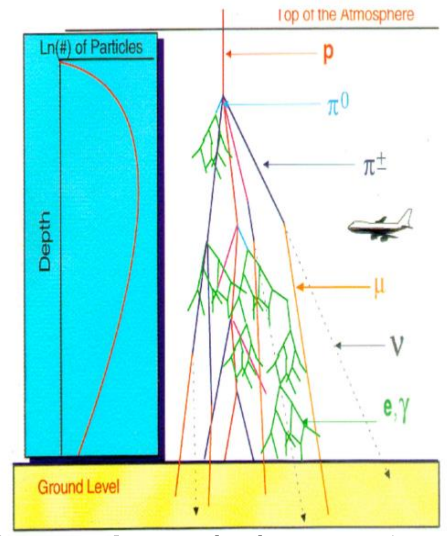


Figure 1. Theory of Pfotzer Maximum. *Shows the decay of subatomic particles entering Earth's atmosphere, which generate the Pfotzer maximum.*[5]

II. Methods and Procedure

One of the first challenges faced in measuring the count of comic rays was in securing the Geiger counters so they could withstand the extreme turbulence of high altitudes. Using Solid Works and a 3D printer, we designed a base that could secure the Aware RM-60 to the POD (see Fig 2). This base allowed the collection of data while protecting the Geiger Counter and the other instruments within the POD. The rectangular extrusion held the RM-60, while the two side slots attached to the structural support rods within the POD. The bottom slot secured the pressure, temperature and humidity probe that protruded from the POD.

Each Geiger counter contains a tube filled with an inert gas; the outer shell of this chamber is an electrical cathode, while an anode wire runs through the center. Particles incident upon the gas cause ionization and the flow of current. The internal circuit is seen in Fig. 6 with an Oscilloscope probing the output pin other the GC. The voltage pulses caused by incident particles were measured and documented.

As mentioned before, particles entering our atmosphere will collide with the nuclei of gas molecules and then possibly decay to produce many secondary particles. An example of one such process is the decay of a high energy charged pion into a muon and neutrino.

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \tag{1}$$

The muons are able to reach the Earth's surface due to two main properties: They travel relatively slow compared to pions and they can penetrate a large amount of material without interacting. This is an important fact used in the analysis of our data.

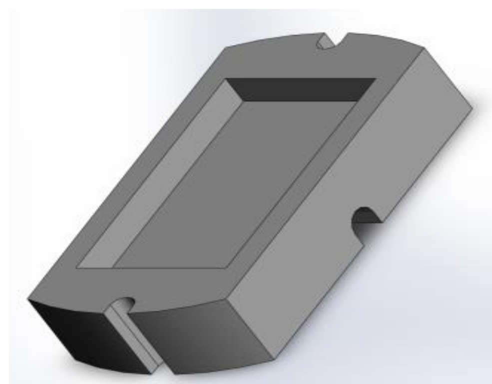


Figure 2. Geiger counter Base. *Design of Geiger counter base generated in SolidWorks and printed on 3D printer.*

III. Instrumentation

The Aware Electronics Geiger counter will be held in place inside of the POD, as mentioned before. The POD will then be encased in plastic and then wrapped in foam to protect it. Next, the Vernier Radiation Monitor will be wrapped in 1/16 inch lead and secured to the outside. Finally, another layer of foam adds yet another layer of protection. A concept diagram of our POD is seen in Fig. 3. Each Geiger counter has a LND 712 halogen-quenched tube with a mica end window of 1.5 to 2.0 mg/cm^2. Because the density of mica is 2883 mg/cm^3, the thickness of the end window is 5.2 to 6.9 µm. It is very thin to allow as much radiation into the tube as possible.The cross sectional area of each Geiger counter is 1.815 cm^2 and the volume is 7.4 cm^3.

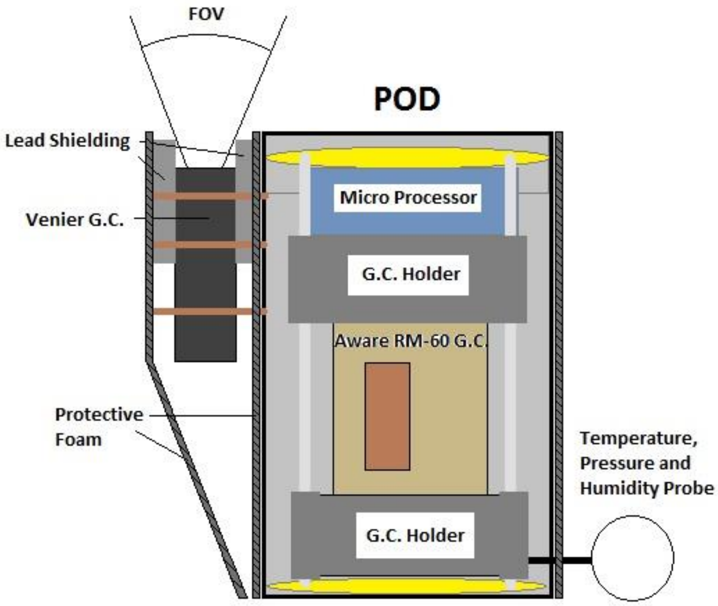


Figure 3. POD Contents. *The arrangement and contents of the POD that was flown on the night launch.*

Figure 4. Final Product. *The POD wrapped in foam before launch.*

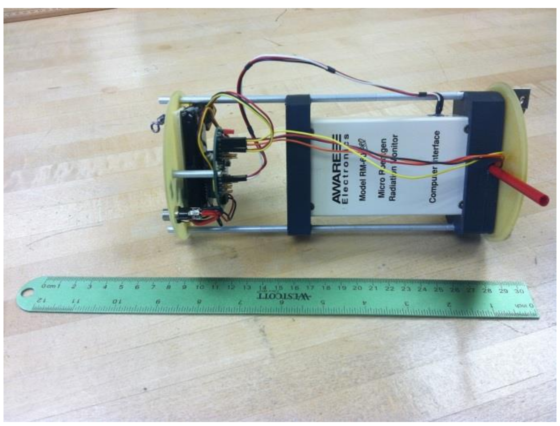


Figure 5. POD Interior. *The inside of the pod with RM-60 Geiger counter held by base.*

IV. Flight Data

As predicted by theory, we found that the maximum count rate occurred between 15 and 20 km above Earth's surface (See Figs. 8, 9, and 11). The primary cosmic rays began scattering at this point. At lower altitudes (<4 km) the count rate has been consistently stable throughout each of our tests. Our original hypothesis was that cloud cover and humidity affected our results but the recent data calls that hypothesis into question, as the night flight was clear and yet showed similar trends. The Vernier Radiation Monitor count rate seemed to continue growing past the Pfotzer maximum (See Fig. 9). This may be due to a cascade effect from the lead shielding. The lead shielding had the same effect as the atmosphere and created a shower of secondary particles that passed through the lead and were detected by the Geiger counter. This caused the increased count rate.

V. Analysis and Results

The goal of this project was to determine the particle count rate throughout the atmosphere and to study the differences between the Geiger Counters flown at multiple times of day. We found that the cheaper, more compact Vernier Radiation moniter delivered comparable results to the trusted Aware RM-60 Geiger Counter. Also, the day and night launches showed very similar trends which suggests that the particles ejected from the sun are not the primary source of counts.

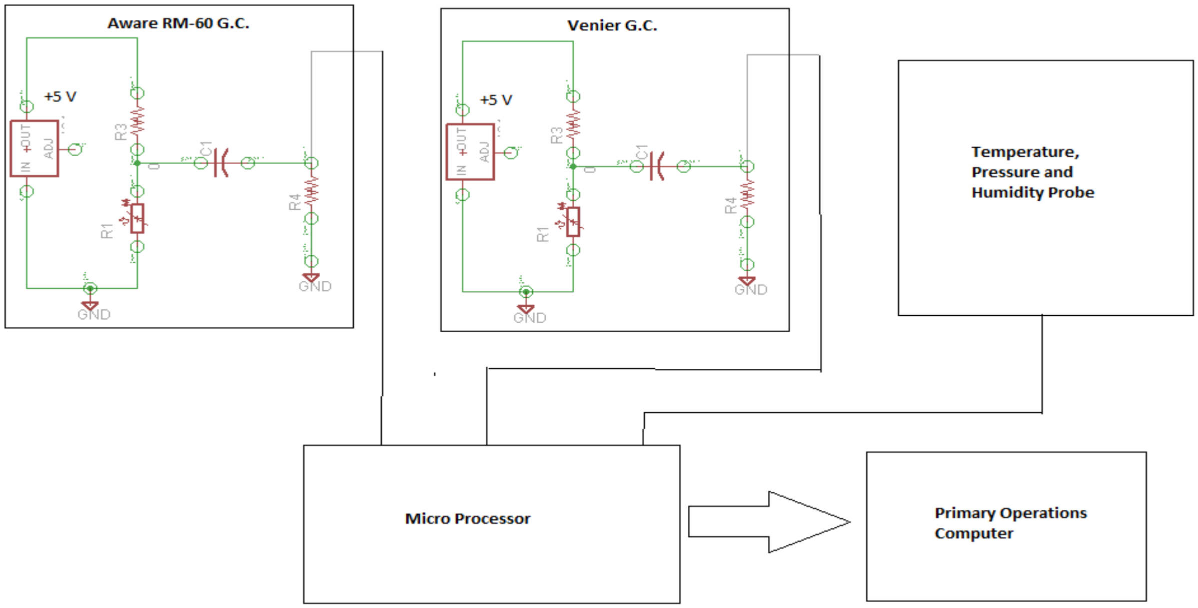


Figure 6. System Interface Layout. *Block diagram of the Geiger counters and sensor probe interfacing with the microprocessor.*

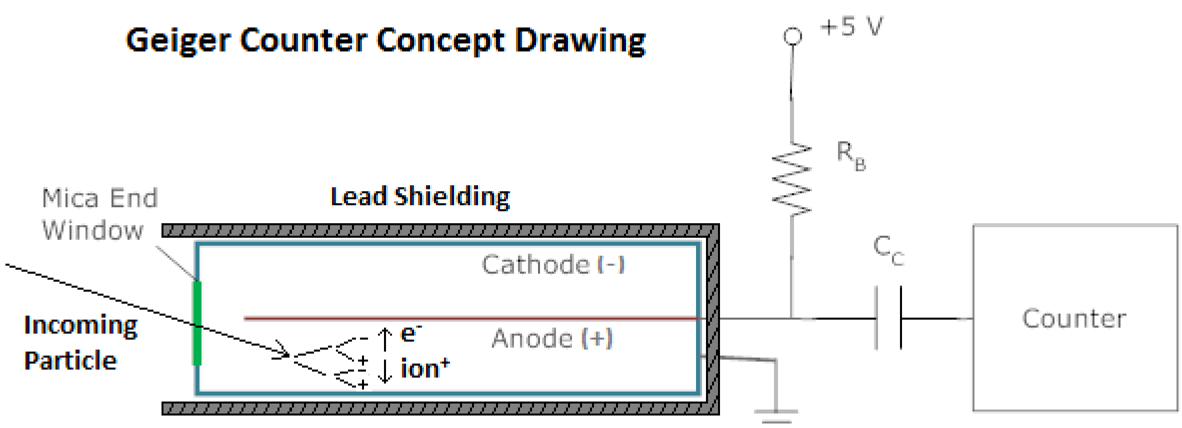


Figure 7. Concept Drawing. *Particles enter through the Mica End Window and create electron-ion pairs by collisions with gas molecules. Electrons are attracted to the positive anode, creating a current.*

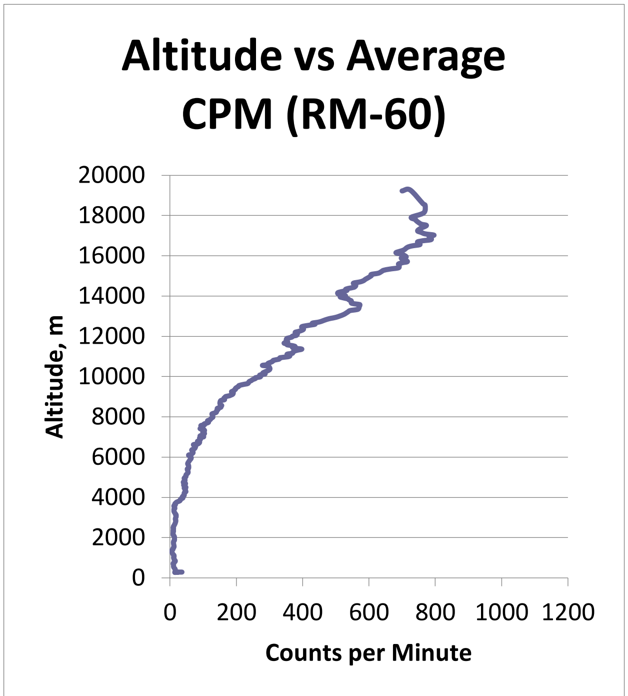
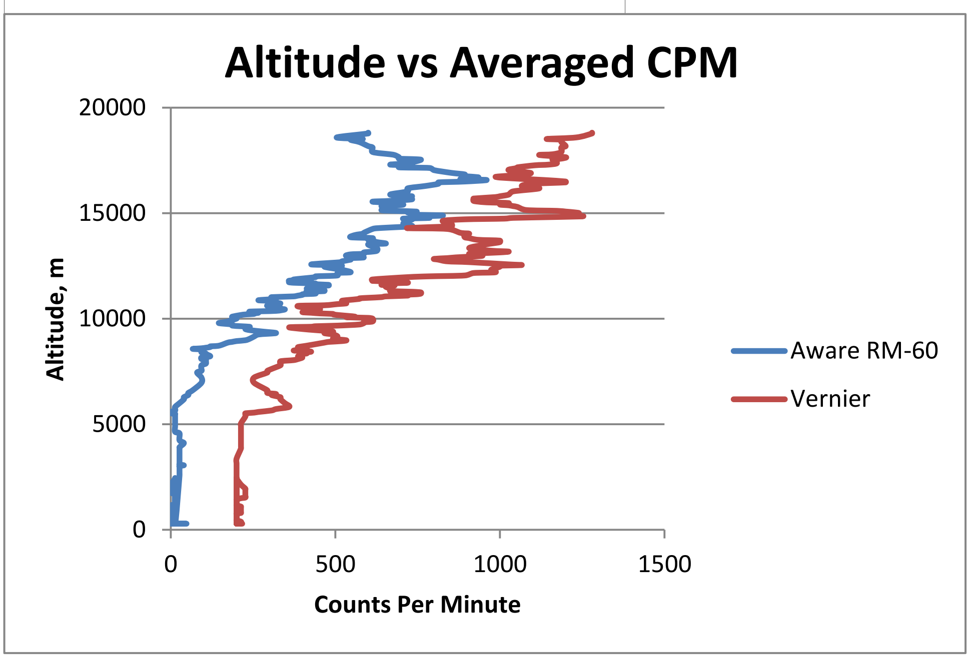


Figure 8. Altitude Plot. *(Left) The data from the daytime launch using the RM-60 G.C on March 9, 2013.*

Figure 9. Altitude Plot. *(Below) The data from the night launch of the RM-60 G.C on April 22, 2013. The data from the Vernier Radiation Monitor is offset by 200 CPM for comparison to the RM-60.*



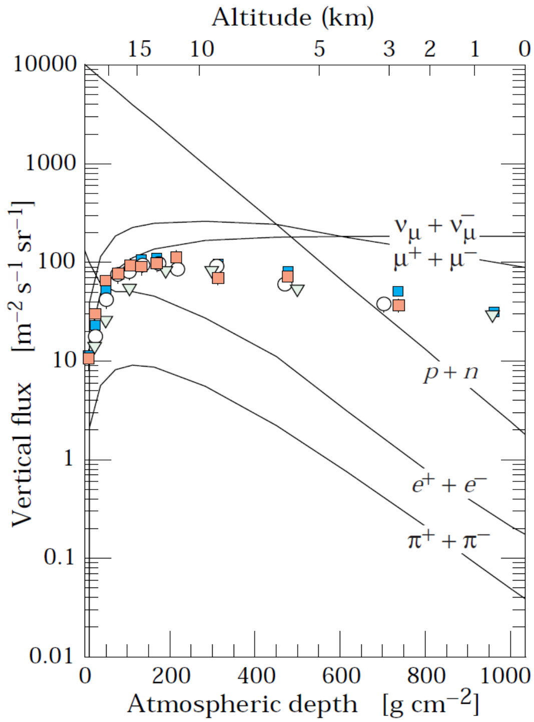


Figure 10. **Particle Flux.** *A plot of the flux of different particles vs the atmospheric depth.*[1]

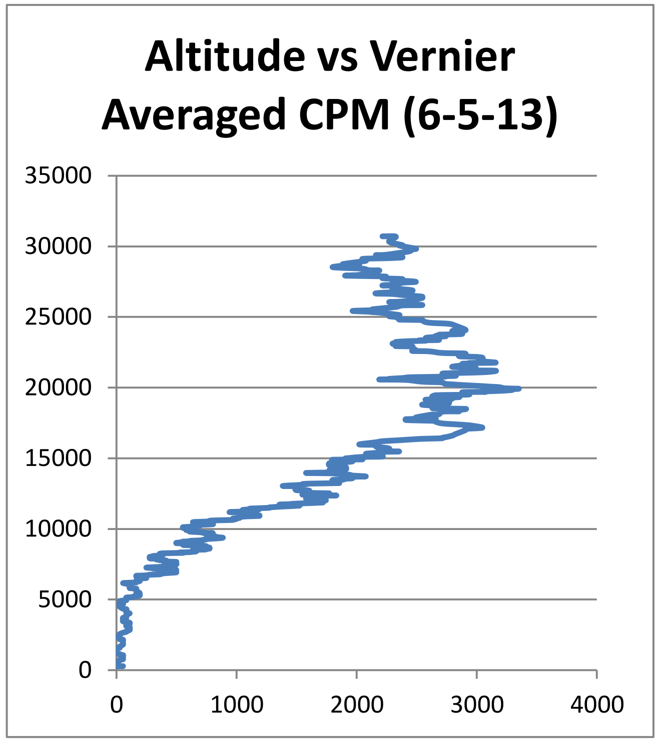


Figure 11. **Altitude Plot.** *The final daytime launch data collected by the Vernier GC on June 5, 2013.*

VI. Conclusion

After analyzing our data and studying other reports on this topic, we believe that the cause of our constant count rate at altitudes below 4 km is due to the relatively constant flux of muons in that region. The points on Fig. 10 show the measurements of μ^-. Below 4 km, the constant muon count dominates the flux but afterwards, the proton and neutron flux begins to become more significant. This causes the increase in counts that is seen in Figs. 8, 9 and 11. There is not a significant difference between the cosmic rays detected at day as opposed to at night. This supports the generally accepted fact that most cosmic rays come from outside our solar system rather than from our sun. In following flights, we shall add greater lead shielding to test our hypothesis of the cascade effect for thin shielding; a high amount of shielding should decrease particle counts. Additional flights are scheduled for future publishing in the Academic High-Altitude Conference.

Acknowledgments

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[3]*Cosmic Ray Measurements*, Gordon McIntosh, 3rd Annual AHAC, 2012.

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[5]http://www.centronast.com/archives/10