Abstract

Cherenkov Radiation produces a ring on the imager of the detector. Compact, light and inexpensive RICH detectors could improve access to particle astrophysics for researchers working with strict mass, volume or budget constraints. The purpose of this project is to build such a RICH detector, using off the shelf components that can withstand the stresses of rocket flight. The prototype will be tested in April during a high altitude balloon flight at an estimated 90,000 ft altitude where cosmic ray showers are prevalent. Performance data collected during the balloon flight will be used to improve the device in preparation for use in a sounding rocket payload in June.

1 Introduction

A RICH Detector, or Ring Imaging Cherenkov radiation Detector, can be used to detect cosmic rays by recording images of the Cherenkov Radiation emitted when ionized particles strike a diffractive medium at relativistic velocities.

The present design uses a GoPro Hero whose lens has been replaced with a magnesium fluoride window held flush against the image sensor to serve as the refractive medium.

2 Mission Overview

2.1 Primary Objective

Our primary goal is to construct a Ring Imaging Cherenkov Radiation Detector that can successfully record Cherenkov Radiation samples from the Upper Atmosphere on a DemoSat flight.

2.2 Secondary Objective

The RICH detector should be able to survive the Balloon flight and indicate that it is ready for rocket-flight in CC of CO’s 2016 RockSat payload.

2.3 Learning Objectives

Through this project, we aim to ensure that the RICH Detector that we built can 1) collect data correctly and 2) survive spaceflight environments.

A successful DemoSat test would validate our design, while giving us a chance to hone our analysis methods to understand the data collected.
from the RockSat-C launch as well as possible. An unsuccessful launch would prove that our design needs refinement, giving us a second chance to get the design right for the RockSat-C launch.

3 Design

3.1 GoPro

The GoPro is a portable action camera that is able to save pictures directly to an onboard micro SD card. Normally there is a lens that focuses the light entering the camera onto its onboard CMOS sensor. The GoPro was disassembled and the lens removed to make way for the magnesium fluoride lens. The magnesium fluoride lens was mounted, via a 3D printed cradle, directly to the CMOS.

3.2 Electronics/Software

The GoPro was modified when it was disassembled to allow the flight controller to control every function as if someone was pressing the buttons on the unit itself. To do this, this inputs for the buttons of the GoPro were linked via wires to the flight controller. The flight controller would then use these lines to virtually mimic the action of pressing the GoPros buttons.

3.3 Budget/Parts List

RICH detector budget: $500

<table>
<thead>
<tr>
<th>Part</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoPro Hero 3+ Silver</td>
<td>1</td>
<td>$250</td>
</tr>
<tr>
<td>Magnesium Fluoride Lens (3mm Length, 12.7mm Diameter)</td>
<td>1</td>
<td>$150</td>
</tr>
<tr>
<td>3D Printed Casing</td>
<td>1</td>
<td>~$5 (price varies)</td>
</tr>
</tbody>
</table>

Table 1. Parts list

4 Testing

4.1 Pre-DemoSat Testing

The testing plans were formulated in accordance with the potential points of failure to ensure that reliability was maximized and probability of failure was minimized.

4.1.1 Drop Test

In case the balloon’s parachute failed the payload must survive a crash landing. Hence, the payload was dropped so that it would fall at terminal velocity. The payload survived the test.

4.1.2 Cooling Test

Since the electronics need to operate at -80 C (the ambient temperature at maximum altitude), they were placed inside a cooler with dry ice to see if they could remain functional at that temperature. The electronics passed the test.

4.1.3 Vacuum Chamber

At maximum altitude, the ambient pressure is expected to drop to nearly vacuum levels. Since the electronics need to operate in such conditions, a vacuum chamber was used to perform the test, which the electronics passed.

4.1.4 Battery Life and Data Storage Test

A battery life and data storage capacity test was conducted. The RICH detector was operational for five hours before the battery life was exhausted. The battery life surpasses requirements for both the balloon and rocket flight. In five hours the RICH detector collected 10 GB of data out of 16 GB of memory.

4.2 Expected Results from DemoSat Flight

A series of JPEG images will be collected during flight. We expect some of the images to contain Cherenkov Radiation produced by high energy particles impacting the RICH detector. An increase in both intensity and frequency of particle hits are expected as the payload reaches the Pfotzer maximum around 45,931 to 82,000 ft.
4.3 Post-DemoSat Testing

Post-flight testing will be conducted to check functionality of the detector for its sounding rocket flight on the CC of CO payload and to assess any issues that may have occurred during the balloon flight. It will be put through a battery life test and image collection test.

5 Expected Results

An increase in the frequency of particle hits on the detector and an increase in the intensity of Cherenkov Radiation (brighter rings) produced by these hits are expected as the balloon increase altitude, and is exposed to higher energy particles in the upper atmosphere.

6 Flight Readiness

The payload was put through a series of environmental tests (see Testing) and operated properly. The results of the testing indicate that the RICH detector and payload are ready for the flight conditions of a balloon flight.

7 Data

7.1 Pre-Balloon Flight

Over 300 images were collected while the RICH detector was exposed to Strontium-90, a low dosage radiation source that produces 542 KeV beta radiation, in an attempt to produce Cherenkov Radiation on ground before flight.

7.2 Data from DemoSat Launch

This data will be added after the flight.

7.3 Data from RockSat Launch

This data will be added after the flight.

7.4 Analysis Methods

7.4.1 Low Pass Filter Analysis

The biggest hindrance to identifying Cherenkov radiation traces is photographic noise. One of the most effective ways of reducing such noise is through a low-pass filter. A low pass filter is a type of signal filter that only attenuates frequencies above a certain cutoff frequency, passing signals below this cutoff frequency. Any frequencies below the cutoff frequency are passed.

This analysis will allow random noise to be effectively cancelled out, allowing Cherenkov traces to be more easily identified. Though Low Pass properties can be realized in a number of algorithms, Fourier analysis will be used in depth on the complex end of the spectrum, as well as moving averages on the simple end. Additionally, filters with finite and infinite responses will be employed.

7.4.2 Thresholding/Binary Image Analysis

Turning the pixel values of an image into a range of values that can be represented as grey-scale or blue-red scale of varying intensity will allow us to see smaller variations in pixel values by limiting the color range to one scale. We will than replace each pixel in an image with a black pixel if the image intensity is less than a constant set or white if the intensity is greater than the constant threshold value.

We will find the threshold value using a number of techniques. Histogram, clustering, object attribute, and Otsu’s Method to name a few.
8 Conclusions

![Image 1. Preliminary RICH image](image1.png)

In conclusion, using a modified GoPro as a RICH detector shows promise of returning viable data collection of Cherenkov Radiation produced from high energy particles. Being able to use a GoPro as an off-the-shelf RICH detector means a more compact and inexpensive RICH detector could be utilized by researchers working under a variety of constraints. The results of the environmental testing show the RICH detector has the durability required for a balloon flight and will be able to collect data throughout the flight. Although further analysis is required, preliminary analysis of the RICH images from the ground test indicate our analysis techniques can extract data from the RICH detectors imager. The data collected by the imager after the balloon flight will be utilized to refine our analysis techniques and prepare the detector for the flight on a RockSat-C experiment.