CDR
Critical Design Review

Hobart and William Smith Colleges

12.04.16
TEAM MEMBERS

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SECTION ONE

MISSION OVERVIEW
Mission Overview

- Our mission is to measure atmospheric muon flux with a solid state scintillator, the intensity of different visible wavelengths with a Hamamatsu spectrometer through an optical port, and use Geiger detectors to model the mitigation of gamma and beta radiation with different levels of shielding.
- Furthermore, we will also include an outreach program to work with students at the high school and middle school level in Geneva, New York, to promote and advance students’ interest in Science, Technology, Engineering, and Mathematics (STEM)
Muon Detector Mission Overview

- This experiment will measure the muon flux through a solid state scintillator.
- We will integrate a temperature probe so that we can account for the change in muon flux in respect to temperature.
- We expect there to be a positive correlation between height and Muon flux.
- This would give us a better understanding of the breakdown of cosmic rays.
Mission Overview: Expected Results

- Muon Flux: We expect to find a maximum muon flux within the atmosphere, as muons are formed when cosmic rays break down.
- Spectroscopy: Light intensity should increase the higher we get in the atmosphere.
- Radiation: Radiation levels should increase as we exit the atmosphere. We will be able to analyze lead, kevlar, mylar, and a controlled variable (no shielding).
- Benefits: Scientists would better understand the makeup of our atmosphere and we would give Primary School students an introduction to aerospace research.
Mission Overview: Expected Results

- The HWS Outreach Program expects to
  - Increase student opportunity and participation in Science, Technology, Engineering and Mathematics.
  - Teach students about electronics, 3D printing, payload design, and workshop.
  - Have high school and middle school students work with a college institution, college professors, and college students.
  - Encourage kids to attend college
  - Increase high school and middle school college campus visits to physics and architecture department.
  - Have students gain experience working on a rigorous project.
  - Teach students how to push boundaries and get out of their comfort zone.
  - Have their Radiation Sensor Geiger Counter Kit be sent into space attached to a rocket.
  - Watch a rocket launch online
Theory & Concepts: Outreach Team

- In order to promote and advance students interest in Science, Technology, Engineering, and Mathematics (STEM), local schools will be provided with Geiger Counter Kit - Radiation Sensors.
- The Geiger Counter - Radiation Sensors made by the individual teams will be used on the HWS research payload. There will be multiple detectors on the research payload, which will increase the amount of data our team will receive from radiation shields and Radiation data.
Theory and Concepts: Cosmic Rays

- Primary Cosmic Rays enter earth's atmosphere in the following distribution: 90% Protons, 9% Alpha Particles, and one percent heavier particles. (Chaisson McMillan)
- PCR's breakdown when entering the earth's atmosphere forming secondary particles.
- These include Kaons, Electrons, Protons, and Pions.
## Charged Particles

<table>
<thead>
<tr>
<th>Particle</th>
<th>Accepted Mass (MeV/c²)</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muon</td>
<td>105.6583745(24)</td>
<td>-1</td>
</tr>
<tr>
<td>Pion</td>
<td>139.570 18 (35)</td>
<td>+1</td>
</tr>
<tr>
<td>Kaon</td>
<td>493.667(13)</td>
<td>+1</td>
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<tr>
<td>Electron</td>
<td>0.510998928(11)</td>
<td>-1</td>
</tr>
<tr>
<td>Proton</td>
<td>938.272046(21)</td>
<td>+1</td>
</tr>
<tr>
<td>Alpha</td>
<td>3727.379378(23)</td>
<td>+2</td>
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</tbody>
</table>
Flux vs Altitude at Low Atmosphere

(N. Ramesh, M. Hawron, C. Martin, A. Bachri)
Previous Research: Spectroscopy

Solar Radiation Spectrum

- Sunlight at Top of the Atmosphere
- 5250°C Blackbody Spectrum
- Radiation at Sea Level

(University of Minnesota)
Rocket Flight and Expected Results

Altitude (km)

- All systems activated
- Begin data collection

Medium Muon Flux, Radiation, and Light Intensity
Altitude: 75 km
$t \approx 1.3$ min

End of Orion Burn
Altitude: 52 km
$t \approx 0.6$ min

Apogee
High Muon Flux, Radiation, and Light Intensity
Altitude: ≈115 km
$t \approx 2.8$ min

Medium Muon Flux, Radiation, and Light Intensity
Altitude: 95 km
$t \approx 4.0$ min

Splash Down
Payload Turns off
Altitude: 52 km
$t \approx 15$ min

Altitude: 52 km
$t = -3$ min
Success Requirements

**Minimum Success Requirements**
- Muon flux but not temperature data
- Consistent spectral images
- Radiation Data from our control Geiger Muller detector

**Comprehensive Success Requirements:**
- Muon flux with temperature data
- Consistent spectral images
- Radiation data from all of our Geiger Muller detectors
System Overview
Design
Vertical Dimensions
Spectrometer Mount

Spectrometer Positioning
Scintillator Plate Encasement

*All thicknesses are ¼”
Bottom Plate
Bottom Plate Continued

Length: 8"
Width: 5.25"

Customizable Board where all Geiger Müller KIta will be condensed onto one board and connected to the four Geiger Müller Tubes.
Top Plate
System Design

Wallops starts operations at T - 3 minutes.
Changes Since PDR

Radiation Shielding:

There will be four Geiger Muller Kits on the very top of the payload, each shielded with different materials.

This design was changed because we wanted to minimize crosstalk and test the most amount of materials as possible.
Off-Ramps

Potential Modifications to Project

Remove two Geiger Muller Detectors

- Reduces weight
- Reduces cost
- Potentially limits crosstalk.
Subsystem Design Section

- Subsystem A: Radiation Shielding/Outreach
- Subsystem B: Muon Detection
- Subsystem C: Spectrometry
Radiation Shielding
Radiation Shielding

Our team wants to maximize the amount of materials possible. In order to follow through with this plan, we will condense four Geiger Muller kits into one board and run jumper wires from the bottom of the canister to four Geiger tubes at the top of the canister.

Our plan is to cover each tube with a different material. However, we found that the attenuation is dependent on how much the material blocks energy radiation particles per square inch. Therefore, the thickness of the material across the four tubes will not be uniform.
Radiation Outreach Program

- Our team also wants to perform an outreach program to work with students at the high school and middle school level in Geneva, New York, to promote and advance students’ interest in Science, Technology, Engineering, and Mathematics (STEM)

- We will have High School and Middle School Students construct a Radiation Sensor Geiger Counter Kit. (Reference Next Slide)
Radiation Outreach Schedule

**Timeline 2016-17:**
*Outreach items in black.*
*Major items listed in blue.*
*HWS items listed in red.*

**Spring 2017 Schedule**

- 1/9/2017: Information Meeting and RockSat-C Sign up at Geneva Middle/High School
- 1/18/2017: 2nd Information Meeting and RockSat-C Sign up at Geneva Middle/High School
- 1/20/2017: High School and Middle School Teams are selected. Meeting times are defined
- 1/23/2017: Progress Update Teleconference
- 1/24/2017: Acceptance Information Meeting and Supply Mightyohm Geiger Counter Kit Radiation Sensor
- 1/27/17: RockSat-C Outreach Team Campus Visit and Tour
- 1/31/2017: Teams begin assembling Radiation Sensor.
- 2/7/2017: Outreach Program Progress Update
- 2/13/2017: Subsystem Testing Review Teleconference
  Outreach Program Visit and Sit in on teleconference
Radiation Outreach Schedule

2/13/2017  Final Payment Due
3/6/2017   Progress update Teleconference
3/7/2017   Outreach Program Teams Visit and Sit in on teleconference
3/10/2017  Outreach Program Progress Update
3/14/17    Outreach Program Lab Work at HWS Physics Lab (3D Printing)
3/17/2017  Outreach Program Progress Update
3/21/17    Outreach Program Lab Work at HWS Physics Lab (3D Printing)
3/24/2017  Outreach Program Progress Update
3/27/17    Outreach Program Lab Work at HWS Physics Lab (Class Sit In)
4/3/2017   Integrated Subsystems Testing Review Teleconference
3/28/17    Outreach Program Progress Update
4/3/2017   Critical Review
## Radiation Outreach Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<tbody>
<tr>
<td>4/7/2017</td>
<td>Outreach Program Progress Update Critical Review</td>
</tr>
<tr>
<td>4/10/2017</td>
<td>RockSat-C Payload Canisters Sent to Customers Pending receipt of final payment*</td>
</tr>
<tr>
<td>4/10/2017</td>
<td>Progress Update Teleconference</td>
</tr>
<tr>
<td>4/14/2017</td>
<td>Final Outreach Progress Presentation and Review</td>
</tr>
<tr>
<td>4/24/2017</td>
<td>Decide on four Outreach teams for implementation to HWS Payload</td>
</tr>
<tr>
<td>4/24/2017</td>
<td>Full Mission Simulation Test Report Presentation Teleconference</td>
</tr>
<tr>
<td>5/22/2017</td>
<td>Outreach Program Teams Visit and Sit in on teleconference</td>
</tr>
<tr>
<td>6/1/2017</td>
<td>Progress Update Report</td>
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</table>
| 6/1/2017   | Outreach Program Teams Visit and Sit in on teleconference

*Possible Program Telecon*
### Radiation Outreach Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
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<tbody>
<tr>
<td>6/5/2017</td>
<td>Preliminary Check-In Procedure Document Due</td>
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<tr>
<td>6/5/2017</td>
<td>Launch Readiness Review Document Due</td>
</tr>
<tr>
<td>6/14/2017</td>
<td>Travel to Wallops Flight Facility</td>
</tr>
<tr>
<td>6/15/2017</td>
<td>Visual Inspection at Refuge Inn</td>
</tr>
<tr>
<td>6/16-19/2017</td>
<td>Vibration/Integration at Wallops</td>
</tr>
<tr>
<td>6/21/2017</td>
<td>Presentations to next years RockSat-C</td>
</tr>
<tr>
<td>6/22/2017</td>
<td>Launch Day</td>
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<tr>
<td></td>
<td>Outreach Team Live Feed of Launch Wallops-Geneva</td>
</tr>
<tr>
<td>7/7/2017</td>
<td>Preliminary Launch Results Document Due</td>
</tr>
<tr>
<td>7/21/2017</td>
<td>Final Report Due</td>
</tr>
</tbody>
</table>
System Block Diagram

- Arduino Uno
- Power
- Radiation Particles
- Geiger Müller Radiation Detector
- Material will enclose the Geiger tube. As of now, our team plans to place four Geiger tubes on the payload.
- Data Collected and Stored on SD Card
Geiger Muller Kit
Subsystem Design: Radiation Shielding

- Four Geiger Muller tubes will be dismantled from their boards and arranged in a way that would better fit in the canister, as shown in the previous diagram.
- The circuitry components will be placed on one circuit board at the bottom of the payload.
- Each Geiger tube will be covered with a different shielding material, which will help us detect which shielding materials attenuates radiation best.
Subsystem Design: Radiation Shielding

Our team reached this design decision in order for us to test the largest number of materials on the payload.

The Geiger tubes will not touch any conducting surfaces.

Moreover, we planned the square-like shape of the Geiger tubes in order to expose all tubes with their maximum surface areas.

There are risks to this design: crosstalk. Crosstalk may occur because of the close proximity of all the tubes.
Muon Detection
Block Diagram of Moun Detector, Photomultiplier
Electrical Design for Muon Detector

- Capacitor
- Diode
- Resistors
- Ground
- 'And' gate

Electrical Diagram of Square Waving Berkeley Circuit.
Manufacturing Plan: Mechanical

Materials/Parts Needed for Payload

- Aluminum top and bottom plates, structure rods, encasements and scintillator plates
- Plastic casings for batteries (can be 3D printed)
- Various hardware (screws, bolts, nuts, washers, etc.)
Electrical Elements

Materials/Parts Needed for Payload

- Arduino(s)
- Temperature probe
- Batteries
- Silicon Photomultipliers
- Terminal inputs for battery connections
- Spectroscope
- ADC circuit
- Data storage unit (SD Card)
#include <SimpleTimer.h>

// There must be one global SimpleTimer object.
// More SimpleTimer objects can be created and run,
// although there is little point in doing so.
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUIS 2

// Setup a oneWire instance to communicate with any OneWire
// devices (not just Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUIS);

// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(oneWire);

SimpleTimer timer;
// print current arduino "uptime" on the serial port
void DigitalClockDisplay() {
    int h,m,s,sil;
    s = millis() / 1000;
    m = s / 60;
    h = s / 3600;
    sil = millis()-(s*1000);
    s = s - m * 60;
    m = m - h * 60;
    Serial.print(h);
    printDigits(m);
    printDigits(s);
    printDigits(sil);
    Serial.println();
}

void printDigits(int digits) {
    Serial.print("\"\"");
    if(digits < 10)
        Serial.print('0');
    Serial.print(digits);
    
void setup(void) {
    // start serial port
    Serial.begin(9600);
    Serial.println("Dallas Temperature IC Control Library Demo");
    // Start up the library
    sensors.begin(); // IC Default 9 bit. If you have troubles consider upping it 12.
    // Ops the delay giving the IC more time to process the temperature measurement
    timer.setInterval(750, DigitalClockDisplay);
    }

void loop(void) {
    sensors.requestTemperatures(); // Send the command to get temperatures
    // Serial.println("DONE");
    Serial.print("Temperature for Device 1 is: ");
    Serial.print(sensors.getTempCByIndex(0));
    Serial.print(" at ");
    timer.run();
    Serial.println();
}
Muon Detector Risk Prevention

- Prelaunch data collection testing
- Prelaunch impact testing
- Prelaunch jerk/acceleration testing

(Dayananda, Mathes et al.)
### Power Budget (Muon detector)

<table>
<thead>
<tr>
<th>Component</th>
<th>Max Voltage (V)</th>
<th>Current (mA)</th>
<th>Start time (s)</th>
<th>Running Time (s)</th>
<th>Watts (mW)</th>
<th>Milliamp hours (mAh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Uno/Temp probe</td>
<td>12V</td>
<td>50</td>
<td>-180</td>
<td>1320</td>
<td>600</td>
<td>18.34</td>
</tr>
<tr>
<td>Berkley Circuit</td>
<td>5V</td>
<td>50</td>
<td>-180</td>
<td>1320</td>
<td>250</td>
<td>18.34</td>
</tr>
<tr>
<td>SiPM</td>
<td>25 V</td>
<td>0.36</td>
<td>-180</td>
<td>1320</td>
<td>8.64</td>
<td>0.132</td>
</tr>
</tbody>
</table>

We will be experimentally verifying that these measurements are correct.
Prototyping/Analysis
Temperature Probe Testing

There have been several developments with the temperature probe.

- We now have an operational temperature probe with an accompanying timer.
- We are currently testing the accuracy of the probe against its advertised $\pm 0.5$ °C, margin of error.
- We have started creating a testing environment out of a cardboard box. We will place the detector and temperature probe inside the box and slowly heat it up with a hairdryer. We will then record the average muon flux at different temperatures.
Cardboard Box with temperature probe inside the box to measure the current temperature.
Flux vs Angle Test
Manufacturing Plan
Manufacturing Plan: Electrical Elements

Materials Needed to be Manufactured/Soldered:

- Geiger Muller kits. Through the outreach program, students in the local Geneva area will work in groups to solder the Geiger Muller kits.
- The Geiger Muller kits will be combined and resoldered onto one circuit board by our team. The circuit board will be located on the bottom of the payload and connected to the four Geiger Muller tubes at the top of the payload.
- Temperature probe will be soldered to jumper wires in order to be in connection with an Arduino Uno.
Success Requirements for Radiation Detector

Minimum Success Requirements

● Receive data on radiation attenuation from the control variable—the Geiger tube with shielding material.

Comprehensive Success Requirements:

● Receive data on radiation attenuation from all four Geiger muller tubes.
Code for Counting Radiation on GM Tube

```c
#include <iostream>

int main()
{
    int counter = 0;
    while (true)
    {
        // Code to count radiation
        counter++;
        if (counter == 10)
        {
            counter = 0;
        }
        std::cout << counter << std::endl;
    }
    return 0;
}
```

This code initializes a counter and counts radiation detections in a loop. When the counter reaches 10, it resets to 0 to avoid counting beyond the threshold.
Risk Management of Radiation Shielding

● One worry present with any electronic system is the potential for electronic signals from one sensor to influence the readings of another. To ensure that this crosstalk is kept to a minimum we will be using insulated wires to transmit the readings from the Geiger Muller detectors, and will maximize physical distance between the detectors.

● Another Risk is that the Geiger Muller detectors will be unable to survive the stresses present at launch. To minimize the risk of structural damage we will insure that the detectors are firmly affixed to the top most plate within the capsule.
# Weight budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass Estimate</th>
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<tbody>
<tr>
<td>Scintillator Plate (x2)</td>
<td>1.983 lbs</td>
</tr>
<tr>
<td>Shielding Material and Geiger Tubes</td>
<td>1.1595 lbs</td>
</tr>
<tr>
<td>Aluminum Plate Encasements (x4)</td>
<td>8.088 lbs</td>
</tr>
<tr>
<td>Top Plate</td>
<td>1.678 lbs</td>
</tr>
<tr>
<td>Batteries</td>
<td>≈0.5 – 1 lbs</td>
</tr>
<tr>
<td>Canister Mass</td>
<td>6.5 lbs</td>
</tr>
<tr>
<td>Temperature Probe</td>
<td>0.013 lbs</td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td><strong>19.9215 ± 1 lbs</strong></td>
</tr>
<tr>
<td><strong>Center of Mass</strong></td>
<td>4.21 inches from bottom of payload</td>
</tr>
</tbody>
</table>
Radiation Shielding Materials

- Control (no shield)
- Lead
- Kevlar
- Mylar
Spectroscopy
Spectroscopy System Components

- Encasement
- Spectrometer
- Breakout Board
- Neutral Density Filter
Block Diagram

- Arduino Uno
- Sunlight
- Spectrometer
- Data Collected and Stored on SD Card
- Power
Component Block Diagram
Previous Experiments

Oversaturation

Useful data

First spectra taken (Calibration)
Spectrometer Improvements and Testing

- Increase neutral density filter strength
  - Filter strength > 1200 nm
- Take more data per time interval.
- We will shine increasingly higher intensity light at the spectrometer until we reach an upper bound where our data is no longer readable.
- We will also test that the filter does not prevent detection of lower intensity light.
Logistics
System Hierarchy
Weekly Schedule and Availability

- Weekly meetings every Friday from 2:30 to 3:30 PM. and Sunday from 4-5pm
- Weekly dinners on Saturday beginning at 6.
- Most work completed in subsystems at designated individual hours.
## Contact Matrix

**RSC 2017 Contact List for: Hobart and William Smith Colleges**

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role/Position</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Person? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zahra Arabzada</td>
<td>Student Researcher</td>
<td><a href="mailto:zahra.arbzada@hws.edu">zahra.arbzada@hws.edu</a></td>
<td>(860) 593-1476</td>
<td>No</td>
</tr>
<tr>
<td>Cody Rivera</td>
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<td><a href="mailto:cody.rivera@hws.edu">cody.rivera@hws.edu</a></td>
<td>(716) 256-8126</td>
<td>Yes</td>
</tr>
<tr>
<td>Duniya Syed</td>
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<td><a href="mailto:duniyasayed4@gmail.com">duniyasayed4@gmail.com</a></td>
<td>(310) 596-9238</td>
<td>Yes (green card)</td>
</tr>
<tr>
<td>Emily Kreps</td>
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<td><a href="mailto:emily.kreps@hws.edu">emily.kreps@hws.edu</a></td>
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<td>Yes</td>
</tr>
<tr>
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<td><a href="mailto:jesse.maltese@hws.edu">jesse.maltese@hws.edu</a></td>
<td>(831) 334-5091</td>
<td>Yes</td>
</tr>
<tr>
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<td>(216) 280-7040</td>
<td>Yes</td>
</tr>
<tr>
<td>Christopher Demas</td>
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<td><a href="mailto:Christopher.Demas@HWS.edu">Christopher.Demas@HWS.edu</a></td>
<td>(315) 663-1875</td>
<td>Yes</td>
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<tr>
<td>Frank Oplinger</td>
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<td><a href="mailto:Frank.Oplinger@HWS.edu">Frank.Oplinger@HWS.edu</a></td>
<td>(203) 512-1038</td>
<td>Yes</td>
</tr>
<tr>
<td>Jeff Rizza</td>
<td>Student Advisor</td>
<td><a href="mailto:Jeffrey.Rizza@HWS.edu">Jeffrey.Rizza@HWS.edu</a></td>
<td>(845) 594-4895</td>
<td>Yes</td>
</tr>
<tr>
<td>Peter Spacher, Ph.D.</td>
<td>Faculty Advisor</td>
<td><a href="mailto:Spacher@HWS.edu">Spacher@HWS.edu</a></td>
<td>(585) 507-6558</td>
<td>Yes</td>
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<tr>
<td>Ileana Dumitriu, Ph.D.</td>
<td>Faculty Advisor</td>
<td><a href="mailto:Dumitriu@HWS.edu">Dumitriu@HWS.edu</a></td>
<td>-----</td>
<td>Yes (green card)</td>
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</tbody>
</table>
Questions

- Can the detector go to the edges of the canister?
- Should we make the pylons shorter than the height of the canister so that it can be attached easily?