Preliminary Design Review

Team Members:
Jeffrey Rizza
Lisa Ditchek
Matthew Sanders
Christopher Demas

Advisors:
Ileana Dumitriu, Ph.D.
Peter J. Spacher, Ph.D.
Our Project: Theory and Concepts
Muon Overview

- Muons are leptons, related to electrons
- Mass of approx. 105.6 MeV/c², about 200x larger than an electron
- Formed as secondary products of interactions between cosmic rays and atmospheric particles
- Atomic nuclei collide with atmospheric molecules, producing pions. These pions decay into muons

\[
\begin{align*}
\text{Cosmic rays:} & \quad H^+ \\
\text{Pions decays into muons} & \quad \pi^+ \rightarrow \mu^-
\end{align*}
\]

- Mean lifetime is 2.2 μs, but because of the particles relativistic speeds, muons are able to travel much farther than normal
Previous Research
Muon Flux

- Experimental data showing the flux of muons at various altitudes
- Muons were detected underwater, and increased with height
- Flux increases steadily from sea level, maximum flux around 15km, then above that decreases sharply

Bachri et al, 2011

Gaisser, 2005
Overview
- BESS detector was used to measure muon flux at 2,770 m above sea level in Japan

Results
- Measured absolute fluxes of atmospheric muons at the top of Mt. Norikura, Japan (altitude of 2,770 m above sea level). Absolute fluxes showed relatively good agreement with theoretical predictions.
Overview
- The BESS-2001 flight kept a lower altitude and was able to detect muons
- Balloon reached altitude of 36 km, descended, and collected cosmic ray data, muon flux obtained
- Measured muon flux at small atmospheric depths of 4.5 g/cm² through 28 g/cm²

Results
- Reproduced atmospheric muons observed at sea level and mountain altitude (Sanuki study)
Overview
- Vertical fluxes of positive and negative muons were detected at two locations, Tsukuba, Japan at sea level (30 m above sea level) and in Lynn Lake, Canda (360 m above sea level)

Set up
- Time of flight (TOF) scintillator hodoscope measured velocity of particles
- Trigger was provided by coincidence between the top and bottom scintillators of TOF counters

Results
- Atmospheric pressure increases, flux decreases
- Temperature has less effect on flux
- Solar modulation affects flux
- Observed vertical fluxes of muons in momentum range from 0.6 to 20 GeV/c
Our Project: Mission
Our Project: Mission

Mission: The purpose of our experiment is to measure the flux of muons at various altitudes within the atmosphere, and to determine if there is a muon flux in space. The primary tool to accomplish this objective is a solid-state scintillation detector with a silicon photomultiplier.

The four main components of this mission will be:
1. Measuring muon flux density throughout the flight
   i. Variations in muon flux within different layers of the atmosphere
   ii. Determine the potential existence and altitude of a critical point(s) for muon generation in the atmosphere
2. Determine the velocity of the muons
3. See how acceleration of the rocket influences muon flux detection
4. Determine if muons are in space, and thus a possible maximum altitude of muon formation

In addition, we wish to analyze features of the atmosphere with a low-resolution spectrometer such as:
1. Chemical composition at different altitudes
2. Doppler shift in the acquired spectra
3. Cyclical pattern in the spectral intensity, due to rotation of the rocket
Our Project: Mission

- **t ≈ 1.3 min**
  - Altitude: 75 km

- **t ≈ 1.7 min**
  - Altitude: 95 km

- **Apogee**
  - t ≈ 2.8 min
  - Altitude: ≈115 km

- **t ≈ 4.0 min**
  - Altitude: 95 km

- **End of Orion Burn**
  - t ≈ 0.6 min
  - Altitude: 52 km

- **t ≈ 4.5 min**
  - Altitude: 75 km

- **t ≈ 5.5 min**
  - Chute Deploys

- **t ≈ 15 min**
  - Splash Down
    - end of data collection

- Data collection begins at T-60 seconds
- All systems on
- Begin data collection
# Top Level Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Payload fit within the canister</td>
<td>Inspection</td>
<td>Visual confirmation and measurement</td>
</tr>
<tr>
<td>Payload will sustain 25g and vibrational characteristic</td>
<td>Test</td>
<td>The payload will be subject to these conditions during testing in June.</td>
</tr>
<tr>
<td>outlined by RockSat-C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payload will weight 20 ± 0.2lbs</td>
<td>Inspection</td>
<td>Payload will be weighed to confirm that it is within the expected range.</td>
</tr>
<tr>
<td>Payload will have a Center of Gravity in the 1”x1”x1”</td>
<td>Mathematical calculation and test</td>
<td>We will devise a test to ensure that we meet the COG requirement</td>
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</tbody>
</table>
Requirements

Mission Requirements:
• Have a working SiPM that counts the number of muons at certain times during the flight.
• Integrate a spectrometer to take spectral images during the length of the flight

Minimum Success:
• Store data for number of muons collected at various times during the flight

Comprehensive Success:
• Count the number of muons during the length of the flight with SiPMs to determine the flux and velocity of the muons
• Obtain continuous spectral images during the length of the flight
System Design: Physical Model
Note:
Dimensions of specific components on following slides
Bottom Plate Mechanical Drawing
Scintillator Plate Encasements
Mechanical Diagram (Bottom View)
Scintillator Plate Mechanical Diagram
Top Scintillator Plate Encasement
Assembly Standoffs
Top Plate w/ Standoffs Mechanical Drawing
## Mass Estimate and Center

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass Estimate</th>
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<tbody>
<tr>
<td>Scintillator plate (x2)</td>
<td>1.975 lbs</td>
</tr>
<tr>
<td>Aluminum Plate encasing (x4)</td>
<td>8.529 lbs</td>
</tr>
<tr>
<td>Bottom Plate</td>
<td>1.963 lbs</td>
</tr>
<tr>
<td>Top Plate</td>
<td>2.154 lbs</td>
</tr>
<tr>
<td>Electronics (Arduino, Wires, amplifier, shaping, SiPM, Spectrometer, power supply)</td>
<td>≈ 1-2 lbs</td>
</tr>
<tr>
<td>Canister mass</td>
<td>≈3.9 lbs</td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td><strong>19.521 lbs ± 1 lbs</strong></td>
</tr>
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</table>

**Center of Gravity:** ~4.12in from the bottom of the plate in axial direction
System Concept of Operation

Wallops starts operations at T-60 sec

System power is activated

Microcontroller

SD Card

Power Supply
Applies Voltage

Power

DATA

SiPM₁

SiPM₂

Spectrometer

Power

Power

Data Amplification

SHAPING
Optical Attachment to Port

Connection of Fiber Optic Cable to the Optical Port.

INTERNAL VIEW

EXTERNAL VIEW

Securely Attached to Payload.
RSK.1: Objective aren’t met IF SD Card fails
RSK.2: Strain Put on Power Supply budget IF flight time is delayed
RSK.3: Objectives aren’t met IF payload cannot survive launch environment (mechanical strain)
RSK.4: Objectives aren’t met IF Arduino or Microcontroller fails in-flight.
RSK.5: Objectives aren’t met IF payload does not survive the launch environment (such as vibrational effects on contact of the SiPM with the scintillator material and Fiber Optic Cable connection to the optical window).
Risk Mitigation

Risk Explanation:

RSK.1: SD Card fails

RSK.2: Strain Put on Power Supply

RSK.3: Mechanical strain

RSK.4: Arduino or Microcontroller fails in-flight.

RSK.5: vibrational effects on contact of the SiPM with the scintillator material and Fiber Optic Cable connection to the optical window.

Risk Mitigation Strategy:

RSK.1: Back up memory drive

RSK.2: Extra battery life (x2)

RSK.3: Sturdy construction to withstand strain

RSK.4: (Most likely will not be a problem)

RSK.5: In lab testing to determine design that provides best contact of SiPM to the scintillator material and connection of fiber optic cable to port window.
## Team Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Agenda</th>
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| 11/8-10/14 | **Work on Individual Responsibilities**  
Chris: Block Diagrams, Critical Interfaces Schedule, Risk Mitigation Chart, General Research (15, 20, 28, 31)  
Jeff: 3D Model with dimensions (mass & rough center of g), Requirement Verification General Research (16-19, 22, 24)  
Lisa: Research (research done with Muon detection in the past), Components List and rough price estimation (9-12, 40)  
Matt: Research (SiPM), find time to go into the lab to work more with the photomultipliers (9-12, 35) |
| 11/11/14   | Meeting to Discuss Draft of PDR                                                                                                                                                                          |
| 11/12/14   | Meeting to Finalize PDR                                                                                                                                                                                 |
| 11/14/14   | PDR Teleconference                                                                                                                                                                                    |
| 11/15-30/14| Delegation of Responsibilities  
More testing with Photomultipliers                                                                                                                                                                   |
| 12/5/14    | CDR Presentation                                                                                                                                                                                       |
Our Project: Team Organization

Advisors:
Ileana Dumitriu Ph.D
Peter Spacher Ph.D

Co-Lead
Contact liaison
Christopher Demas

Co-Lead
Jeffrey Rizza

Researcher:
Matthew Sanders

Researcher:
Lisa Ditchek

Programing Specialist:
(Potentially needed)
# Our Project: Contact Matrix

RSC 2013 Contact List for: Hobart & William Smith Colleges

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Person? (Y/N)</th>
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<tbody>
<tr>
<td>Christopher Demas</td>
<td><a href="mailto:chrispother.demas@hws.edu">chrispother.demas@hws.edu</a></td>
<td>(315)-663-1875</td>
<td>Y</td>
</tr>
<tr>
<td>Jeff Rizza</td>
<td><a href="mailto:jeffrey.rizza@hws.edu">jeffrey.rizza@hws.edu</a></td>
<td>(845)-594-4895</td>
<td>Y</td>
</tr>
<tr>
<td>Matthew Sanders</td>
<td><a href="mailto:matthew.sanders@hws.edu">matthew.sanders@hws.edu</a></td>
<td>(585)-278-3839</td>
<td>Y</td>
</tr>
<tr>
<td>Peter Spacher Ph.D.(Advisor)</td>
<td><a href="mailto:spacher@hws.edu">spacher@hws.edu</a></td>
<td>(315)-781-3853</td>
<td>Y</td>
</tr>
<tr>
<td>Ileana Dumitriu Ph.D. (Advisor)</td>
<td><a href="mailto:dumitriu@hws.edu">dumitriu@hws.edu</a></td>
<td>(315)-781-4601</td>
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### Our Project: Availability Matrix

**Hobart and William Smith Colleges**

**Fall 2014 RS-C Team Availability Matrix**

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<tr>
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*For now this is our revised availability matrix*
Action Items for CDR

Component Costs and Sources:
- Silicon photomultiplier
- Scintillator plate material
- Arduino unit (model)
- Square wave shaping circuitry

Further Experimentation:
- Work with photomultipliers that we already have access to
- Take measurements with spectrometer that we have access to

Determine Access to Facilities/Tools:
- Molding aluminum components

Refine Design:
- Half canister vs. whole canister
- Potentially eliminating spectrometer