Left to right: Kemal Turksonmez, Tyler Hanzlik, Rousseau Nutter, Lauren St. Peter, Frank Oplinger, Bobby Hooper

Advisors: Chris Demas and Jeff Rizza
Mission Overview
HWS High Altitude Muon Detection Experiment
Finalized Mission Statement: The purpose of our experiment is to determine the flux of muons at various levels within the atmosphere using a plastic scintillator detector with a solid state SiPM.
Mission Overview cont.

- Four main specific mission components:
  - Measure muon flux density during flight
  - See how acceleration of rocket influences muon detection
  - See how temperature determines muon count
  - Improve upon detection from 2015
  - Determine how temperature affects muon count
Expected Results

- Muon flux will vary throughout different levels of the atmosphere
- Muon count will increase with altitude until it reaches its peak, at which point it will begin to decrease
- Higher canister temperatures will cause a higher muon count in comparison due to effect of temperature on the SiPM
  - When compared to controlled temperature testing
Operations During Flight

- Data collection begins at $T - 180$ seconds (Allows proper time for system boot up and baseline data collection).
- All systems on
- Begin data collection

$t = -3$ min

Altitude: 75 km

$t ≈ 1.3$ min

Altitude: 75 km

$t ≈ 1.7$ min

Altitude: 95 km

End of Orion Burn

$t ≈ 0.6$ min

Altitude: 52 km

$t ≈ 2.8$ min

Altitude: ≈115 km

Apogee

$t ≈ 4.0$ min

Altitude: 95 km

$t ≈ 4.5$ min

Altitude: 75 km

Chute Deploys

$t ≈ 5.5$ min

$t ≈ 15$ min

Splash Down
-end of data collection
Requirements

- Working solid state muon detector that counts muons throughout flight

- Minimum Success:
  - Accurate collection of muon data throughout the flight

- Comprehensive Success:
  - Obtain more filtered, accurate data than 2015 launch
  - Comparatively analyze data with ground temperature data to determine effect of temperature on muons
Theories and Concepts

HWS High Altitude Muon Detection Experiment
Muon Overview

- Muons are leptons, related to electrons
- Mass of approx. 105.6 MeV/c^2, 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 which decay into muons
Muon Overview cont.

- The mean lifetime of a muon is 2.2 μs,
- Muons travel much farther than the expected distance for its lifetime because it travels near the speed of light.
- More than half of the cosmic radiation at the sea level is made up of Muons.
- At sea level the average muon flux is about 1 muon per square centimeter per minute.
Previous Research cont.

- Scintillation response increases slightly with temperature increase

*Bedder, Sam. “Scintillation dosimetry: Review, new innovations and applications”*
System Overview

HWS High Altitude Muon Detection Experiment
Systems Block Diagram
Temperature Probe

Photomultiplier
Mechanical Design cont.

- Changes since PDR:
  - Circular panel selected based on in lab testing
  - Increased radius of plates
  - Increased scintillator plate thickness
  - Added temperature probe
  - Decided on two photomultipliers
Electrical Design
Electrical Schematic cont.
Electrical Schematic cont.
Electrical Schematic Cont.
Software Design

- Code elements:
  - Counting code to obtain signals from detector output and process by Arduino and store on SD card
  - Currently have working code from 2015 launch
  - Ensure code specifies currently temperature as well as time and altitude
Software Design cont.

- Example code:

```java
if(data[ct] != 0) {
    if(!logFile)
        logFile = SD.open(fileName, FILE_WRITE);
    if(logFile) {
        DateTime datetime = RTC.now();
        // month/day/year   Hour:Minute:Second    millis()
        logFile.print(datetime.month());
        logFile.print("");
        logFile.print(datetime.day());
        logFile.print("");
        logFile.print(datetime.year());
        logFile.print("\t");
        logFile.print(datetime.hour());
        logFile.print(":");
    }
}
```
De-scopes

- De-scopes:
  - Removed initial solar panel
    - Focus on improving experiment results from last year
  - Used same number of photo multipliers as last year
    - Reduces costs
    - Simplify Arduino code
# Power Budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Max Voltage (v)</th>
<th>Current (A)</th>
<th>Start Time (s)</th>
<th>Running Time (s)</th>
<th>Watts</th>
<th>mAh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Uno</td>
<td>12</td>
<td>0.05</td>
<td>-60</td>
<td>1200</td>
<td>0.6</td>
<td>16.67</td>
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<tr>
<td>Berkley Circuit</td>
<td>5</td>
<td>0.05</td>
<td>-60</td>
<td>1200</td>
<td>0.25</td>
<td>16.67</td>
</tr>
<tr>
<td>SiPM</td>
<td>24</td>
<td>0.00036</td>
<td>-60</td>
<td>1200</td>
<td>0.00864</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>0.10036</strong></td>
<td></td>
<td></td>
<td><strong>1200</strong></td>
<td><strong>0.86</strong></td>
<td><strong>33.45</strong></td>
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HWS RockSat-C PDR 2016
## Weight Budget

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<th>Component</th>
<th>#</th>
<th>Lbs</th>
<th>Total (lbs):</th>
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<tbody>
<tr>
<td>Detector</td>
<td>1</td>
<td>6.1</td>
<td>6.1</td>
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<tr>
<td>9 V Battery</td>
<td>3</td>
<td>.11</td>
<td>.33</td>
</tr>
<tr>
<td>15 V Battery</td>
<td>4</td>
<td>.03</td>
<td>.12</td>
</tr>
<tr>
<td>Canister</td>
<td>1</td>
<td>3.35</td>
<td>3.35</td>
</tr>
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</table>

Total: 9.9
Prototyping/ Analysis

Title Slide
SiPM detectors are very sensitive to Voltage changes, possibly even more sensitive than KETEK suggests.

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Slope (muons/second)</th>
<th>1/slope (seconds/muon)</th>
<th>muons/minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.28</td>
<td>0.4033</td>
<td>2.479543764</td>
<td>24.198</td>
</tr>
<tr>
<td>27.23</td>
<td>0.051</td>
<td>19.60784314</td>
<td>3.06</td>
</tr>
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</table>
Effect of Voltage on Counting Rate

- We will need to take into consideration the voltage that we use for the Solid-State Scintillator Detector (i.e. decide on a voltage to use for testing and launch so that the data is comparable).

![Voltage Vs. Muon Count Rate](image-url)
Efficiency of Detector

- Used radioactive source (Cs – 137) to determine whether or not the entire detector’s surface area is sensitive to radiation.

Partitioned Solid-State Scintillator Detector into 1 in\(^2\) segments.
Efficiency of Detector

Used radioactive source (Cs – 137) to determine whether or not the entire detector’s surface area is sensitive to radiation.

- **Results:** The radioactive source did not significantly increase the count rate on any portion of the detector. Gamma rays are not detected at high efficiency.*

  *This is good but not necessarily what we were looking for*

- **Future Direction:** Look at the response from each detector separately instead of looking for coincidental pulses to determine the sensitive area of the detector.
Manufacturing Plan
Mechanical components

Manufactured

- Aluminum for top and bottom plates and encasements
- Aluminum structure rods
- Scintillator plates from Ludlum cut to size in house
- Plastic casings to hold batteries (3D printed)

Procured

- SIPM PM6660 (Photomultipliers) from KETEK
- Scintillator plates from Ludlum cut to size in house
- Various hardware (screws, bolts, nuts, washers, etc.)
Mechanical Manufacturing

Items to be Manufactured

- Aluminum top and bottom plates: cut from aluminum blocks and drill mounting holes
- Aluminum scintillator plate encasements: cut and mill from aluminum blocks, lathe, and drill mounting holes (potentially create molds)
- Cut-out encasements for SiPMs: cut from aluminum blocks and weld into place on encasements
- Cut EJ-200 scintillator plate material into required geometry
- Attachment of mechanical systems to payload
Electrical Components

Materials/Parts to Obtain and solder/manufacture

- Coaxial shielded cable
- Amplifier
- Square-waving circuitry
- PCB (plastic circuit board)
- Arduino
- Silicon Photomultipliers
- Data storage unit (SD card and mount)
- Batteries 9 and 15 volt
Electrical Manufacturing

- Circuits to Construct
- Amplification circuitry: Utilize design from Berkley Lab Cosmic Ray Detector to build our own PCB
- Output to Arduino: Utilize Berkley circuit design to build our own circuitry
- Square-waving circuitry: Utilize Berkley design from last year
- NEW this year—PCB board built to fit on top of the Arduino to miniaturize circuitry and improve space and mass efficiency
Software Manufacturing

Code Elements to Develop

- Counting code to obtain signals from SiPM input and store as output on permanent storage (we have existing code from last year we can improve)
- Code to specify storage format of data (time, altitude, and detector hit correlation)
Time budget/ schedule

- January—acquire all mechanical and electrical components needed
- January-February—proceed with mechanical and electrical manufacturing
- February-March—produce final product to begin testing and data collection
Testing Plan

Title Slide
Electrical Testing

(1) Scintillators/ SiPM Testing
• The scintillator material will be securely assembled to the silicon photomultipliers and surrounded by the aluminum encasement
• A small radioactive source will be placed above the scintillator plates and the output pulses will be for changes in frequency of “hits”

*The system has passed if there is an increased electrical pulses counted due to the radioactive source*
Electrical Testing

(2) Scintillators/ SiPM Testing/ Temperature

- If the silicon photomultipliers and scintillator plate construction is successful, a similar test will be run to test how differing temperatures affect the readings of the silicon photomultipliers.

- The scintillator material will be securely assembled to the silicon photomultipliers and the temperature probe and they will all be surrounded by the aluminum encasement.

*If the silicon photomultipliers are affected by differing temperatures, we will keep running experiments to mimic the temperatures inside the rocket to form a successful way to interpret the data we will collect from the launch. If the readings are not affected, then there is no need to run more testing on the subject.
Electrical Testing

Battery Consumption Period

- The circuits will be run until the batteries are drained. The Arduino will be programmed to collect the total time the system lasts.
  *The system has passed if the battery consumption period is longer than the rockets flight + starting timer*
Initial Testing

(1) Mass Check Testing

• The payload will be weighed to ensure that it fits in the prescribed range of 10 ± 0.1 lbs.

*The system has passed if the weight is within range*
Initial Testing

(2) Center of Mass of Payload

- The center of mass will be calculated by hand

*The system has passed if the mass of the Payload is centered*
(3) Vibrational testing for SiPM on scintillator

- To ensure that the apparatus can withstand vibration, the apparatus will be subjected to shaking.

- The apparatus will be strapped to a cart with unsymmetrical wheels which will be driven around for 6, 1 minute intervals.

*The system has passed if the apparatus withstands movement and shaking.*
Initial Testing

(4) Rigidity of Payload

- To ensure the rigidity of the payload, the apparatus will be subjected to shaking and vibrational movements.
- The apparatus will be strapped to a cart with unsymmetrical wheels which will be driven around for 6, 1 minute intervals.

*The system has passed if the payload sustains structural integrity.*
(5) Rotational Rigidity of the payload

- To ensure the rigidity of the payload, the apparatus will be subjected to rotational tests.

- The payload will be spun on a Potter’s wheel

*The system has passed if the payload maintains structural integrity*
Project Management Plan
## Budget Assessment:

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Cost ($)</th>
<th>Quantity Required</th>
<th>Total Cost ($)</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Arduino Mega</td>
<td>Arduino</td>
<td>$0.00</td>
<td>1</td>
<td>$0.00</td>
<td>Already possess one</td>
</tr>
<tr>
<td>Al. Ext. Rod</td>
<td>MSC</td>
<td>$8.27</td>
<td>3</td>
<td>$24.81</td>
<td>Extra lengths for prototyping</td>
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<tr>
<td>Si Photomultiplier</td>
<td>Ketek</td>
<td>$400.00</td>
<td>3</td>
<td>$1200.00</td>
<td>Have confirmed supplies acquisition</td>
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<td>Scintillator Plate Material</td>
<td>Eijen</td>
<td>$106.00</td>
<td>2</td>
<td>$212.00</td>
<td>Eijen supplied</td>
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<tr>
<td>Aluminum</td>
<td>HWS Physics Dept</td>
<td>$300.00</td>
<td>N/A</td>
<td>$300.00</td>
<td>For encasements and plates</td>
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<tr>
<td>Batteries</td>
<td>Duracell</td>
<td>$7.50</td>
<td>8</td>
<td>$60.00</td>
<td>Extras as backups</td>
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<td>Electrical/Hardware</td>
<td>Varied</td>
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<td>???</td>
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<td>Canister Space</td>
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<td>Travel Expense</td>
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<td>HWS Student Govt.</td>
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<td>$20,996.81</td>
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</table>
Special thanks to Ketek for supplying the team with 3 SIPM photomultipliers (2 to use and 1 extra).

- Expecting to receive $2000 from NYSG
- Drafting letters of request for funding from other companies but waiting to send letters out until NYSSG response.

- Other possible funding sources include:
  - Lockheed Martin
  - Thermo Fisher Scientific
  - ITT Exelis
  - Harris
  - Pictometry
Our Project: Team Organization

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

Co-lead
Frank Oplinger

Mentor
Chris Demas

Co-lead
Rousseau Nutter

Mentor
Jeff Rizza

Researcher:
Bobby Hooper

Researcher:
Kemal Turksonmez

Researcher:
Tyler Hanzlik

Funding:
Lauren St. Peter
### Availability Matrix

<table>
<thead>
<tr>
<th>Hobart and William Smith Colleges</th>
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<tbody>
<tr>
<td>Fall 2014 RS-C Team Availability Matrix</td>
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<tr>
<th>Time</th>
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<th>Tuesday</th>
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<tr>
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<td>4:00 PM</td>
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**Our Project: Contact Matrix**

RSC 2015 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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</thead>
<tbody>
<tr>
<td>Frank Oplinger</td>
<td><a href="mailto:frank.oplinger@hws.edu">frank.oplinger@hws.edu</a></td>
<td>(203)-512-1038</td>
<td>Y</td>
</tr>
<tr>
<td>Christopher Demas</td>
<td><a href="mailto:christopher.demas@hws.edu">christopher.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>Lauren St. Peter</td>
<td><a href="mailto:lauren.stpeter@hws.edu">lauren.stpeter@hws.edu</a></td>
<td>518-598-8556</td>
<td>y</td>
</tr>
<tr>
<td>Kemal Turksonmez</td>
<td><a href="mailto:kemal.turksonmez@hws.edu">kemal.turksonmez@hws.edu</a></td>
<td>980-307-5174</td>
<td>Y</td>
</tr>
<tr>
<td>Tyler Hanzlik</td>
<td><a href="mailto:Tyler.hanzlik@hws.edu">Tyler.hanzlik@hws.edu</a></td>
<td>715-741-1070</td>
<td>y</td>
</tr>
<tr>
<td>Bobby Hooper</td>
<td><a href="mailto:robert.hooper@hws.edu">robert.hooper@hws.edu</a></td>
<td>425-985-9523</td>
<td>y</td>
</tr>
<tr>
<td>Roussea Nuter</td>
<td><a href="mailto:Roussea.nutter@hws.edu">Roussea.nutter@hws.edu</a></td>
<td>(413)-313-5535</td>
<td>y</td>
</tr>
<tr>
<td>Peter Spacher</td>
<td><a href="mailto:spacher@hws.edu">spacher@hws.edu</a></td>
<td></td>
<td>y</td>
</tr>
<tr>
<td>Ileana Dumitriu</td>
<td><a href="mailto:dumitriu@hws.edu">dumitriu@hws.edu</a></td>
<td>269-312-3540</td>
<td>y (green card)</td>
</tr>
</tbody>
</table>
Conclusion

- Build two Gieger detectors for in lab testing
  - To be finished before break
- Obtain parts for scintillator detector
- Continue to search for funding
Questions

- Who builds the dividing plate?
- Is it provided?
- When will we be put into contact with our other group?
- What is the total power capacity?