CDR Presentation Outline

• Section 1: Mission Overview
• Section 2: System Overview
• Section 3: Subsystem Design
  – 3.1: Science Subsystem
  – 3.2: Structural Integration & Protection Subsystem
  – 3.3: Power Distribution Subsystem
  – 3.4: Data Acquisition Subsystem
• Section 4: Prototyping/Analysis
• Section 5: Manufacturing Plan
• Section 6: Testing Plan
• Section 7: User Guide Compliance
• Section 8: Project Management Plan (PMP)
1.0 Mission Overview

*Steven Hard*
Mission Statement

To embark on a collaborative effort with academic institutions across the state of West Virginia for development and expansion of knowledge and practical experience in designing, building, launching, and operating space payloads.

Value of Participation:

• Enhance domain knowledge of next generation engineers & scientists (students)
• High synergy and academic collaboration
• Results shared publically to benefit SmallSat community
WV-SPACE RSX-17 Mission Overview

• **Goal:** Develop and test several science and engineering experiments for space operations

• **Objectives:**
  - Capture NIR and LWIR images of Earth from space
  - Build and test an adaptable payload launcher in space
  - Study launching dynamics and heat of re-entry
  - Test SSD for ultra-compact plasma spectrometer CubeSat payload
  - Determine direction of charged particles, study DNA breaks from radiation, and measure $O_3$ concentrations
  - Autonomously acquire an astronomical target and image
  - Analyze tensile stress of ABS plastic in space
**Theory and Concepts: NIR Vegetation Imaging**

**Background**
- Pigment in plant leaves (chlorophyll) strongly absorbs visible light (from 0.4 to 0.7 µm) for use in photosynthesis.
- Cell structure of the leaves strongly reflects near-infrared light (from 0.7 to 1.1 µm).
- The more leaves a plant has, the more these wavelengths of light are affected.

**Purpose**
- Assess the vegetation health along the east coast
- Identify areas of sand or drier vegetation
- Predict drought
- Determine if science apparatus is feasible for orbital mission

\[ \text{NDVI} = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}} \]
Theory and Concepts: Ejection & Heat of Re-entry

• Payload Ejection Pod
  – Hook’s Law
  – $F = K \cdot D_x$
  – 1.5 lbf

• Atmospheric Re-entry Probe
  – RF Comms
    • Expected range ~1mi
    • 900 MHz
  – Heat of re-entry
    • Perfect Gas Law
    • Real (equilibrium) Gas Law
    • Real (non-equilibrium) Gas Law
    • Frozen Gas Law
Theory & Concepts: Solid State Detector

• The SSD has a detection threshold of a few keV
• The SSD and electronics package will provide measurements of energetic electrons (> 5 keV) in the auroral zone
• Typically those electrons arise from impulsive events in the magnetosphere
  – Magnetic reconnection
  – Losses from the radiation belts (e.g. wave-particle scattering)
• SSD measurements would improve our understanding of loss mechanisms of radiation belt particles and acceleration processes that create those energetic electrons
  – Achieved through correlation of data from the Van Allen Probes mission
Theory and Concepts: Charged Particles

- **Background**
  - γ ray photons have λ between 0.03-0.003 nm
  - x-rays have λ between 0.2-0.1 nm
  - Geiger counter detects radiation within 0.1 to 200 mSv/h
  - Radiation causes ionization in counter that is detected at anode as voltage

- **Concept**
  - **Particle Detector**:
    - Arrangement of silicon detectors allows particles to strike the panels such that 3D direction can be estimated via flux
  - **Force Modulation Microscope (FMM)**:
    - Near apogee, cosmic radiation will damage sampled DNA, causing strands to break
    - Breaks will be captured and analyzed by an on-board camera

- **Purpose**
  - Quantify radiation and map with change in altitude
  - Hopefully detect gamma ray burst
  - Evaluate detector for orbital mission uses
  - Study breaks in various DNA samples due to radiation in space
Theory & Concepts: Astronomical Targeting

- Concept
  - Using an alt-az-mount with 2 servos for a pointing system that will use database information from astronmetry.net and simple spherical trigonometry to target and identify stars of interest
  - “Plate solution” software engine employed to determine initial pointing of an alt-az mount and thereby the required motion of the mount to reach the nearest target
  - Subsequent fine-tuning corrections can be made in the same manner until the target is within an acceptable range of the image center
Theory & Concepts: ABS Yield Strength

• Theory
  - $A_{\text{rectangle}} \times S_y = F$
  - Known value for ABS Plastic: $S_y \approx 5780$ psi

• Concepts
  - Due to the vacuum of space and the pressure drop, ABS plastic may become susceptible to outgassing
  - This could possibly lead to the material becoming more brittle
Concept of Operations

- **Launch**: $H = 160 \text{ km} (T = 3 \text{ min})$
- **Apogee**: $H = 0 \text{ km} (T = 0)$
- **Chute deploys**: $H = 10.5 \text{ km} (T = 7.7 \text{ min})$
- **Splashdown**: $H = 0 \text{ km} (T = 15 \text{ min})$
- **Telemetry OFF**: $H = 50 \text{ km} (T = 5.5 \text{ min})$
- **End of Malamute Burn**: $H = 52 \text{ km} (T = 0.6 \text{ min})$
- **Timed Event 1**: $H = 160 \text{ km} (T = 3 \text{ min})$
- **Timed Event 2**: $H = 0 \text{ km} (T = 0)$
- **Launch**: $H = 0 \text{ km} (T = -3 \text{ min})$
- **All systems on**: Begin data acquisition
Mission Operations

T-3min → Turn ON all systems → IDA begin VID data collection → Skin Ejected

First Timed Event

ATA begin target acquisition → SSD begin particle detection → IDA begin NDVI/LWIR image capture → PEP eject ARP → PVD capture FMM image

ATS trigger TSA actuation → Second Timed Event → ARC send packets to MGS → Turn OFF all systems except PVD → PVD collect O₃ levels → Splash
## Timer Events Matrix

<table>
<thead>
<tr>
<th>Event</th>
<th>Time On</th>
<th>Dwell</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE 1</td>
<td>T-180 sec</td>
<td>540 sec</td>
<td>WV-SPACE – PWR On: Turn on power distribution system for all experiments to receive power</td>
</tr>
<tr>
<td>TE-1</td>
<td>T+180 sec</td>
<td>120 sec</td>
<td>WV-SPACE – Systems Go: Longeron 1 / 3 pointing Nadir / Zenith near apogee; Atmospheric Reentry Probe ejection; ABS Tensile Strength boom extension; Astronomical Target Acquisition alt-az lock-on</td>
</tr>
<tr>
<td>TE-2</td>
<td>T+300 sec</td>
<td>60 sec</td>
<td>WV-SPACE – HAM Tx: Longeron 2 pointing Nadir; Amateur Radio Communication transmission initiated</td>
</tr>
</tbody>
</table>

![Diagram](image)
# Top Level Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDA experiment must be able to view earth’s surface while protected against</td>
<td><strong>Test</strong></td>
<td>Coordinate w/ Wallops for pointing and software testing will determine if the frame rate is successfully reconfigured</td>
</tr>
<tr>
<td>harsh environments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARC subsystem must be pointing nadir for at least 30 seconds after “Systems</td>
<td><strong>Demonstrate</strong></td>
<td>Coordinate w/ Wallops for pointing and test ARC subsystem transmits at the specified frequency only during timed event (use PTT)</td>
</tr>
<tr>
<td>Go” event occurs and operate at a frequency of 435 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APE experiment must be pointing nadir during ejection event and must not</td>
<td><strong>Demonstrate</strong></td>
<td>Coordinate w/ Wallops for pointing and generate test cases for all possible failures which could result in premature ejection</td>
</tr>
<tr>
<td>allow premature ejection to occur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATA must be pointing in the zenith direction for at least 30 seconds and</td>
<td><strong>Demonstrate</strong></td>
<td>Coordinate w/ Wallops for pointing and generate test cases for full range of motion for each DOF</td>
</tr>
<tr>
<td>must not reach outside the useable workspace of the alt-az</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVD experiment must be remain powered on during decent to less than 10km</td>
<td><strong>Test</strong></td>
<td>Coordinate w/ Wallops additional battery requirement and test that the battery will not be charged through circuitry</td>
</tr>
<tr>
<td>altitude</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.0 System Overview

Steven Hard
System Definitions

- SPACE: Student Partnership for Advancement of Cosmic Exploration
- WVU-APE: West Virginia University Adaptable Payload Ejection
- WVU-SSD: West Virginia University Solid-State Detector
- WVU-IDA: West Virginia University Infrared Data Analysis
- MU-ATA: Marshall University Autonomous Target Acquisition
- WVSU-PVD: West Virginia State University Particle Vectoring & Deoxyribonucleic Acid (DNA)
- WVUTech-ATS: West Virginia Institute of Technology Acrylonitrile Butadiene Styrene (ABS) Tensile Strength
- PDS: Power Distribution System
- DAQ: Data Acquisition
- SIP: Structural Integration & Protection
System Level Block Diagram

Black – Signal
Blue – Data
Red – 28V
Orange – 5V
Brown – 4V
Systems Overview: System Changes Since PDR

• WVU-APE
  - Scaled down the payload ejection pod cross-section to 3.5” instead of 4.25”
    - Allowed for repositioning to provide clearance for longeron
    - Provided additional clearance for telemetry connector (still have to trim)
  - Using 900 MHz option for wireless comm
  - No changes to mission objectives or requirements

• WVU-SSD
  - SPI bus expander IC will now be used to convert Red Pitaya SPI bus to 16-bit parallel interface
    - Due to difficulty purchasing 16-bit serial-in-parallel-out shift register
  - The circuit design for the detector has been changed to sum all four pixels of the detector together to maximize detection area
  - Add an accelerometer to DAQ board in sealed section to provide a method of correlating experiment data with flight dynamics data and flight time provided by Wallops
  - No changes to mission objectives or requirements

• WVUTech-ATS
  - Only using 1 linear actuator instead of 2 side by side
  - It was decided that it would be very difficult to activate them at the same time with the same force so the team will use 1 actuator
  - No changes to mission objectives or requirements
## Critical Interfaces

<table>
<thead>
<tr>
<th>Interface Name</th>
<th>Brief Description</th>
<th>Potential Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optics Port</td>
<td>WVU-IDA subsystem will need to be contained in a sealed section with a quartz viewport</td>
<td>Design custom enclosure with sealed view port</td>
</tr>
<tr>
<td>PEP Mount</td>
<td>PEP of WVU-APE subsystem will need to be mounted in an orientation such that the launch path is free and clear of any obstructions</td>
<td>Build a precise mechanical model and construct a mockup of deck and longerons</td>
</tr>
<tr>
<td>Telemetry</td>
<td>DAQ subsystem will need to receive telemetry lines from various payloads inside and outside of the sealed section and send a cumulative signal to the Wallops telemetry interface</td>
<td>Prototype wiring harness and pass through connectors and start parsing data to build a cumulative signal</td>
</tr>
<tr>
<td>Main Enclosure</td>
<td>A large sealed section is required to protect the circuit boards and CPUs for the PDS, DAQ, ATS, &amp; PVD experiments and will need to have 2 pass-through connectors for power &amp; telemetry</td>
<td>Build a mockup to fully understand size constraints for integration of boards and connectors. Test o-ring design for water-tight seal in submersion to 8 ft</td>
</tr>
</tbody>
</table>
## RSX 2017 Mass Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Total Mass (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WVU-APE</td>
<td>PEP</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ARP</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PCB</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Sensors/DAQ</td>
<td>0.15</td>
</tr>
<tr>
<td>WVU-IDA</td>
<td>ARC</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>PCB</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Sensors/DAQ</td>
<td>0.15</td>
</tr>
<tr>
<td>WVU-SSD</td>
<td>PCB</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Shield</td>
<td>0.1</td>
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<tr>
<td>MU-ATA</td>
<td>Alt-Az Mount</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Sensors/DAQ</td>
<td>0.1</td>
</tr>
<tr>
<td>WVSU-PVD</td>
<td>PCB</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Sensors/DAQ</td>
<td>0.12</td>
</tr>
<tr>
<td>WVUTech-ATS</td>
<td>PCB</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Sensors/DAQ</td>
<td>0.12</td>
</tr>
</tbody>
</table>

| DAQ       | Heat Sink      | 0.2              |
|           | CPU            | 0.1              |
|           | Wiring         | 0.3              |
| PDS       | Battery        | 0.2              |
|           | PCB            | 0.1              |
|           | Wiring         | 0.3              |
| SIS       | Main Enclosure | 3                |
|           | IDA Enclosure  | 3                |
|           | ATA Enclosure  | 0.5              |
|           | VID Enclosure  | 0.5              |
|           | Mounting Brackets | 0.5     |
|           | Ballast        | 0                |
| Deck      | Half Deck      | 0                |

<table>
<thead>
<tr>
<th></th>
<th>Target Weight (lbf)</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>13.84</td>
</tr>
<tr>
<td></td>
<td>Over(+)/Under(-)</td>
<td>-1.16</td>
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</table>
# Power Budget

## WV-SPACE - RSX2017 Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
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</thead>
<tbody>
<tr>
<td>WVU-APE</td>
<td>4.0</td>
<td>0.20</td>
<td>30</td>
<td>0.80</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>12.0</td>
<td>2.00</td>
<td>3</td>
<td>24.00</td>
<td>0.10</td>
</tr>
<tr>
<td>WVU-IDA</td>
<td>4.0</td>
<td>2.00</td>
<td>20</td>
<td>8.00</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>2.00</td>
<td>20</td>
<td>10.00</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>1.00</td>
<td>20</td>
<td>5.00</td>
<td>0.33</td>
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<tr>
<td>WVU-SSD</td>
<td>5.0</td>
<td>2.00</td>
<td>20</td>
<td>10.00</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>12.0</td>
<td>0.80</td>
<td>20</td>
<td>9.60</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>14.0</td>
<td>0.80</td>
<td>20</td>
<td>11.20</td>
<td>0.27</td>
</tr>
<tr>
<td>MU-ATA</td>
<td>5.0</td>
<td>2.00</td>
<td>30</td>
<td>10.00</td>
<td>1.00</td>
</tr>
<tr>
<td>WVSU-PVD</td>
<td>4.0</td>
<td>0.80</td>
<td>30</td>
<td>3.20</td>
<td>0.40</td>
</tr>
<tr>
<td>WVUTech-ATS</td>
<td>24.0</td>
<td>2.50</td>
<td>3</td>
<td>60.00</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>0.80</td>
<td>20</td>
<td>3.20</td>
<td>0.27</td>
</tr>
<tr>
<td>DAQ</td>
<td>5.0</td>
<td>2.0</td>
<td>30</td>
<td>10.00</td>
<td>1.00</td>
</tr>
<tr>
<td>PDS</td>
<td>28.0</td>
<td>0.8</td>
<td>30</td>
<td>22.40</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11.70</strong></td>
<td></td>
<td></td>
<td><strong>117.20</strong></td>
<td><strong>6.26</strong></td>
</tr>
</tbody>
</table>

**Total Power Capacity**: 6.26

**Over (+)/Under (-)**: 0.00

**# of Flights Margin**: 1.0

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12/6/2016
System Overview: Special Requests

• High Voltage
  – SPD: ~60V
  – Geiger Counter: ~400V

• Extra Battery
  – Used to power O₃ and VID experiment after re-entry
  – 2Ah, 3.7V Lithium cell battery

• Payload ejection

• RF transmission
  – 435 MHz @ 500 mW
  – 928 MHz @ 250 mW
Description of Partnership

• Partners:
  - West Virginia University Team
    - WVU-APE
    - WVU-IDA
    - WVU-SSD
  - Fairmont State University
    - FSU-ARP
    - FSU-MGS
  - Marshall University
    - MU-ATA
  - West Virginia State University
    - WVSU-PVD
  - West Virginia University Institute of Technology
    - WVUTech-PTS
  - NASA IV&V Facility
    - Technical & Financial Support
  - West Virginia Space Grant Consortium
    - Logistics & Financial Support
3.0 Subsystem Design

Steven Hard
3.1 Science Subsystem

Steven Hard
System Overview: Science Design Overview

• Science subsystem consists of 6 different experiments
• All have different but in some cases overlapping design requirements, success criteria, and expected results
• Objectives achieved through combination of timing/pointing requirements and scientific design
3.1.1 Science Subsystem
WVU Adaptable Payload Ejection

Steven Hard
WVU-APE: Mission Success

• Objective(s):
  ➢ Measure the dynamics of an ejected probe into microgravity and study its reentry dynamics

• System Requirements
  ➢ Must sample data at 50 Hz or higher
  ➢ Need structure to support the instrument(s) in-flight
  ➢ Need an ejection system to launch the probe into the atmosphere
  ➢ Must transmit probe data using wireless communication

• Minimum Success
  ➢ Initial communication with the ejected probe is established
  ➢ Probe successfully transmits initial acceleration and rotation rates to the PEP

• Comprehensive Success
  ➢ Probe successfully transmits acceleration and rotation rates along with temperature to the PEP until burnup
WVU-APE: Expected Results

• Payload Ejection Pod
  – Ejection gives ARP tumble rates < 1.5Hz
  – Receive packets from > 1 mile separation

• Atmospheric Reentry Probe
  – Increased vibrations and heat
  – Withstand temperatures up to 1200 deg F
WVU-APE: Subsystem Design

• Power and Data:
  – 4V input @ 2A max
  – 32 GB micro SD card
  – Not using Wallops telemetry
• Mechanical/Electrical Interfaces
  – Isolated sealed section w/ quartz viewport
  – Hermetically sealed SMA connector
  – Hermetically sealed 4-pin power connector
• Hardware
  – RGB camera
  – NIR camera
  – LWIR imager
  – Raspberry Pi3 (x2)
• Subsystem Weight
  – 1.1 lb
• Design Finalizations
  – Fine tuning mounting design for viewport
WVU-APE: De-Scopes and Off-Ramps

• Potential descope if risk of schedule slippage becomes to high
  – Heat of re-entry analysis
• Potential off-ramps
  – ARP camera
WVU-APE: Block Diagram
WVU-APE: Electrical Schematic
WVU-APE: Software Design
WVU-APE: Analysis Results

• Spring constant calculation

\[ F = K \cdot D_x \]

\[ F = 1.5 \text{ lbf} \]

\[ D_x = 3.5'' \]

\[ K = 13.78 \text{ lbm/in} \]

• Closest match found

<table>
<thead>
<tr>
<th>Spring OD</th>
<th>Wire Dia.</th>
<th>Compressed Lg.</th>
<th>Max. Load, lbs.</th>
<th>Rate, lbs./inch</th>
<th>Pkg. Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5&quot; Overall Length</td>
<td>1.218&quot;</td>
<td>0.125&quot;</td>
<td>1.81&quot;</td>
<td>72.00</td>
<td>22.25</td>
</tr>
</tbody>
</table>
WVU-APE: Prototyping Results
3.1.2 Science Subsystem
WVU-Infrared Data Analysis

Steven Hard
WVU-IDA: Mission Success

- Objectives: Build an NDVI/LWIR experiment to fit in a CubeSat, provide visual verification of payload deck, and attempt to send an image to a mobile ground station
- System Requirements:
  - Camera must be able to view earth’s surface and configurable to take video at 60 fps
  - NIR camera and LWIR image must fit within a 1U Cubesat
  - Input voltage of 4 V @ 750 mA max current draw
  - Additional camera must be positioned to view necessary telemetry information
  - Structures to support and protect the instruments in-flight
  - Data collection system to store the measurements (in-flight)
  - RF antenna and ground system for receiving amateur radio packets
- Minimum Success
  - One NIR image of earth’s surface to distinguish landmass and potential vegetation health assessment
  - One LWIR image of the ocean
  - Visual telemetry collected after launch and at apogee
- Comprehensive Success
  - Collect multiple images for analysis and receive image on ground
WVU-IDA: Expected Results

• NIR and Rpi video throughout entire flight and payload recovery at 60 fps
• Extraction of “good” images from video data during flight
  – Good: visibly distinguishable land mass or NIR source
• Expect to create a Normalized Difference Vegetation Index (NDVI) of reflected NIR light intensities (from 0.7 to 1.1 µm) for each good image
  – Index of plant “greenness” or photosynthetic activity
• Payload deck video showing visual indication of probe ejection and any faults experienced during flight
  – Flashing LEDs, payload launcher, structural failure
• Expect to receive an IMU packet and LWIR image on the ground
WVU-IDA: De-Scopes and Off-Ramps

• Scope has not changed
• Potential off-ramps
  – LWIR imager due to software complexity and volume constraints
  – 2nd VID camera due to volume constraints
  – Pan/tilt for 1st VID camera due to software and timing complexity
    • APE gets priority viewing
WVU-IDA: Subsystem Design

• Power and Data:
  – 4V input @ 2A max
  – 32 GB micro SD card
  – Not using Wallops telemetry
• Mechanical/Electrical Interfaces
  – Isolated sealed section w/ quartz viewport
  – Hermetically sealed SMA connector
  – Hermetically sealed 4-pin power connector
• Hardware
  – RGB camera
  – NIR camera
  – LWIR imager
  – Rpis
• Subsystem Weight
  – 1.1 lb
• Design Finalizations
  – Fine tuning mounting design for viewport
WVU-IDA: Block Diagram

NDVI
- RGB Camera
- Ribbon
- GPIO
- I2C
- 32 GB uSD
- 10DOF IMU

LWIR
- LWIR Imager
- NIR Camera
- Ribbon
- GPIO
- Raspberry Pi 3
- 32 GB uSD

VID
- RGB Camera
- Ribbon
- Raspberry Pi 3
- 32 GB uSD

ARC
- TNC
- Antenna
- 435 MHz
- Transceiver
- AFSK

PDS
- 5V
- Serial
WVU-IDA: Software Design
• Used imaging software (Gimp) to process images from a RGB and NIR camera
  – Overlay images as necessary to produce the NDVI result
WVU-IDA: Prototyping Results

• Prototyped RGB and NIR cameras operating together
  – RGB camera, IMU run by master Rpi
  – NIR camera, LWIR run by slave Rpi

• Prototyped Adafruit 10DOF IMU using Arduino mini
  – Working on porting libraries to master Rpi

• Key results
  – Camera configurations fully understood
  – IMU operations understood
3.1.3 Science Subsystem
WVU-Solid State Detector

Greg Lusk
WVU-SSD: Mission Success

- **Objective(s):**
  - Build a solid-state ionized particle detector to decrease mass, volume, power, and high voltage requirements while reducing manufacturing cost through the ability to produce large quantities of identical instruments

- **System Requirements**
  - Noise floor at or below 1keV
  - Sample rate of at least 1MHz
  - Solid state detector
  - Shield on exposed board section
  - >=12-bit resolution ADC

- **Minimum Success**
  - Detect an ionized particle to verify instrument functionality

- **Comprehensive Success**
  - Collect distribution of ionized particle detection through timed event sequence
WVU-SSD: Expected Results

• Establish a steady-state from quiet zone during ascent
• Detect a few particles prior to timed event
• More charged particles falling downward so facing upward
  – Expect increased detection rates during the timed event sequence
WVU-SSD: De-Scopes and Off-Ramps

• Summing four pixel outputs of detector into a single charge sensitive preamplifier has not been tested yet
  – Depending on how feasible this concept ends up being after further researched, it may be off-ramped to simplify circuit design and reduce cost

• To reduce accumulated data and reduce RAM utilization on Red Pitaya, data from the X and Y axis of the accelerometer may not be collected
  – Z-axis data is all that is needed to correlate experiment data to flight dynamics data provided by Wallops
WVU-SSD: Subsystem Design

- Approximately 6W power consumption
- 16-bits of data generated/analog sample
- 16-bits per reading of Y-axis accelerometer
- Experiment will receive 28V from Wallops and locally regulate +5, +/-7V, +/-6V
- Detector board located on exposed section, data acquisition located in protected, sealed section
- Red Pitaya used as data acquisition system
  - Xilinx zynq 7010 dual-core arm + FPGA
  - Built-in 14-bit ADC used for detector sampling
  - Built-in micro SD card used for local storage
    - No data sent over telemetry interface
WVU-SSD: Block Diagram

Sealed Section

Timer provided by Wallops

Analog gain and conditioning

28V

Local voltage regulation:
5V, +/- 7V

Red Pitaya DAQ
- Up to 125MS/s, 50MHz 14-bit analog input
- SD card storage
- Parallel/Serial telemetry interface

Exposed Section

Local voltage regulation:
+/- 6V, up to 100V bias

Charge/Voltage Amp
Solid State Detector
WVU-SSD: Electrical Schematic

Detector Board schematic
WVU-SSD: Software Flow

SSD experiment turns on at T-3 mins.

Config. Sent to FPGA to init. ADC, SPI

Timestamp, new file on SD card, begins sampling ADC, acquiring accelerometer data

Buffer data in RAM and write buffer to SD card

Event timer == HGH when SSD facing stars -> timestamp

Continue ADC sampling, accelerometer acquisition

Event timer == LOW when SSD direction changes -> timestamp

Continue ADC sampling, accelerometer acquisition
WVU-SSD: Analysis Results

- SSD signals typically have (1) a small amplitude – a few mV, (2) a fast rise – tens of ns to μs, and (3) the small pulses “ride up” on one another as the pulses accumulate.
- Steps can be seen in dark blue trace above and are not suitable to be directly digitized.

- The analog conditioning circuitry prepares the signal so it can be accurately digitized.
- Dark blue trace shows the output from the preamplifier: a series of “steps” of a few millivolts, spaced randomly in time, with high frequency white noise superimposed.
- The light blue trace shows the output of the analog preconditioning circuitry, with its 3.2 μsec pole.
- The magenta trace shows the digitally shaped output: it is the peak of this which is detected and binned in the spectrum (performed during post processing).
WVU-SSD: Prototyping Results

Initial testing of detector board has stalled to some extent.
• Plan for testing was initially to use an electron gun, extracted from a CRT to accelerate electrons toward detector in a small vacuum chamber. While electron gun worked, problems developed with aiming the electrons at the small detecting surface.

A small laser was used to test the detector board outside of a vacuum environment
• The laser did not have an affect when pointed at the detector itself, most likely because the laser does not meet the approximately 1 keV threshold of the detector.
• When the laser was pointed at the bond wires leading from the detector to the PCB, the software did accumulate counts due to charging effect.
• Indication that the circuity is working.
3.1.4 Subsystem Design
MU-Automatic Target Acquisition

Rae Stanley
MU-ATA: Mission Objective

• **Objective(s):**
  ➢ Perform flight test / proof-of-concept experiment for an autonomous pointing determination and target acquisition system for astronomical instruments

• **System Requirements**
  ➢ Alt-Az-Mount with 2 servos, a very small camera, a single-axis gyro, a real-time clock, and a raspberry pi to capture an astronomical target

• **Minimum Success**
  ➢ Successful acquisition of one target

• **Comprehensive Success**
  ➢ Determination of initial pointing from image data.
  ➢ Successful slew to nearest target.
  ➢ Obtaining image of the chosen target.
  ➢ Time permitting, acquisition and imaging of additional targets.
WVU-IDA: Expected Results

• A successful test will consist of:
  - determination of initial pointing from image data
  - successful slew to nearest target
  - obtaining image of the chosen target
• For this test a simple optical camera will be used to obtain images
• An optical, white-light camera is used to obtain star images for pointing determination and verification of target acquisition.
• Exact passband is unimportant
• Field of view in the range of 4-8 degrees, depending on bench tests of computation time for pointing determination
WVU-IDA: De-Scopes and Off-Ramps

• Scope has not changed
• Potential off-ramps:
  – LWIR imager due to software complexity and volume constraints
  – 2nd VID camera due to volume constraints
  – Pan/tilt for 1st VID camera due to software and timing complexity
    • APE gets priority viewing
MU-ATA: Subsystem Design

• Power and Data:
  – 5V input @ 2A max
  – 12V input @ 2A max
  – 16 GB micro SD card

• Mechanical/Electrical Interfaces
  – Isolated sealed enclosure Alt-az mount
  – Using parallel interface – 1 byte/sec via serial to DAQ

• Hardware
  – Raspberry Pi 3
  – Miniature wide-field camera
  – 2 miniature servos
  – Gearing mechanism and brackets

• Subsystem Weight
  – 1.1 lb

• Design Finalizations
  – Fine tuning gearing mechanism to get arcminute accuracy
MU- ATA: De-Scopes and Off-Ramps

- None
- This is a proof-of-concept mission
- One successful target acquisition remains feasible
MU-ATA: Block Diagram
MU-ATA: Software Flow
MU-ATA: Analysis Results

- The brackets, mounts, and size of our servos were prototyped.
- The results of this prototyping showed that the L-beam needs to be raised, camera mount needs to be enlarged, legs need to be placed on a base, and there needs to be another component to help store and organize the electrical components.
- Once these issues are resolved, they should meet the project requirements.
MU-ATA: Prototyping Results

- A larger mechanical arm is being used to develop and test software for servo control
3.1.5 Science Subsystem
WVSU Particle Vectoring & DNA

Danford Smith
WVSU-PVD: Mission Success

- **Objective(s):**
  - To build a low-Earth orbit payload capable of measuring flight dynamics, trace gases, radioactive particles, DNA deterioration, and testing limits of GPS

- **System Requirements**
  - Power, SD Memory Card and Micro-Controller

- **Minimum Success**
  - Detection of particles, received GPS coordinates, photos of DNA, detection of $O_3$, and measured acceleration & angular velocity

- **Comprehensive Success:**
  - **Particle Detector**: Alpha, Beta & Gamma Particles detected in 3-axes, the direction of radiation found
  - **Ozone Sensor**: $O_3$ measured in (ppb) in Stratosphere & Troposphere on re-entry
  - **IMU**: Angular Velocity & Acceleration measured in 3-axes
  - **DNA Experiment (DNAE)**: Breaks in six kinds of DNA measured at and near apogee, with the amount of breaks increasing over time
WVSU-PVD: Expected Results

- **Particle Detector**: ~300+ counts/second and direction
- **Gas Sensor**: Between 50 and 250 ppb through the troposphere & stratosphere
- **IMU**: Flight dynamics comparable to those of the rocket's actual acceleration & angular velocity throughout the flight
- **DNAE**: ssDNA and dsDNA breaks
- **GPS**: Acquiring real-time before launch, experimentally determining the limits of U.S.-based GPS modules
WVSU-PVD: Descopes & Off-Ramps

- **Off-Ramps:**
  - In the case that we cannot efficiently receive data from our silicon detector experiment, resort to a Geiger Counter only
WVSU-PDV: Subsystem Design

- **Power:** ~400mA, 5V
- **Data:**
  - For telemetry, we will use the 8-N-1 convention to interface with the DAQ
  - Baud Rate is 4800, but we’d prefer 115200 if available
  - <1kb of data per second, at most 1800 numeric characters generated every 1 second
- **Main Hardware:**
- **Weight:**
  - 122g/0.269lbs
- **Statement on whether this subsystem design is FINAL:**
  - Yes, the Subsystem design is finalized
  - Needs two iterations to test & calibrate final circuit for PVD & other sensors before actually FINAL
  - Microscope design will include additional parts when received
WVSU-PVD: Electrical Design Elements

• We will have two PCBs:
  – PCB1 will be our “Essentials” Board. It will contain our circuitry, Raspberry Pi 0, IMU, DNAE, & GPS.
  – PCB2 will be our “Experiment” Board. It will contain connections to our Particle Detectors and Ozone Sensor.
  – The actual Particle Detectors & Ozone Sensor will be attached to the outside of WVU’s casing.

• The Essentials & Experiment PCB’s will be sandwiched within 1.5” of vertical space.
  – The Raspberry Pi 0 will be between the PCB’s, attached to the bottom and top boards by pegs.
• The GPS will require serial input.
WVSU-PVD: Electrical Pin-Out
WVSU-PVD: Software Flow Chart

**GPS Code (C IDE)**
- Begin Serial Communication with GPS module
- Print time, latitude & longitude to Excel File
- Print time, latitude & longitude to Serial Transmitter buffer

**IMU Code (C IDE)**
- Read x, y, z-axis acceleration output from IMU
- Print x, y, z-axis acceleration to Excel File
- Print x, y, z-axis acceleration to Tx Buffer

**Particle Detector Code (C IDE)**
- Start timer
- If signal is high, increment counter
- If timer = interval, reset timer, reset counter
- Send time, counts to Tx buffer

**Geiger Counter Code (C IDE)**
- Start timer
- If signal is high, increment counter
- If timer = interval, reset timer, reset counter
- Send time, counts to Tx buffer

**Raspberry Pi Code (C IDE)**
- For data from GPS/IMU/Particle Detector/Geiger Counter, Write data to Excel file
- Send data to Tx buffer, transmit data when buffer is full

**Fluorescent Microscope Code (ImageJ API)**
- Start ImageJ
- Analyze fluorescence change every 1 second
- Record location of DNA break/low fluorescence for 5 seconds
- Print location of confirmed break to Excel File
- Send break data to Tx buffer

**Ozone Sensor (C IDE)**
- Read ppm concentration from sensor
- Print concentration to Excel file
- Print concentration to Tx Buffer

RS-232 Rx
WVSU-PVD: Analysis Results

• What was analyzed/tested since PDR
  – Geiger Counter, DNAE

• Results:
  ▪ Geiger Counter works. Counts were similar to last year.
  ▪ Fluorescent Microscope has resolution of 10 Microns. Captured video of *C. elegans* nematodes

• How these results relate to the project requirements
  – Geiger Counter matches its requirements for functionality, making it ready-to-go.
  – For other sensors, results do not meet objectives yet.
WVSU-PVD: Prototyping Results

• What was prototyped?
  – Silicon Particle Detectors, Geiger Counter, DNAE

• What are the key results?
  • The Geiger Counter and DNAE work
  • The Silicon Detectors don’t function properly. Larger detectors will be tested for sensitivity.

• How do these results relate to the project requirements?
  – Meet minimal objectives of Geiger Counter & DNAE.
  – GPS module, ozone sensor haven't been received yet.
WVSU-PVD: Prototyping Results

- Raspberry Pi Camera hooked up to the Raspberry Pi 0 for DNAE prototyping
- Prototyping for the F.M.M. (CMOS Sensor + Dried Nematodes + Sensor Enclosure)
- Geiger Tube hooked to breadboard for radiation testing
WVSU-PVD: Prototyping Results

- Video showing the nematodes that were video-taped using the F.M.M. without filters.
- [https://youtu.be/ro8rOdaKy4o](https://youtu.be/ro8rOdaKy4o) (Video URL)

- Nematodes are ~1/10mm
WVSU-PVD: Prototyping Results

- Circuit 2 Untaped & Taped.
- (Breadboard wires included.)
3.1.6 Science Subsystem
WVUTech ABS Tensile Stress

Conrad Lacey
WVU Tech-ATS : Mission Success

- Objectives:
  - To build a circuit board to measure the flight dynamics of the rocket and an experimental apparatus for a performing a tensile specimen test while the rocket is at its peak
- System Requirements
  - Communicate with tensile stress apparatus to activate it once it reaches the rocket’s peak
  - Have our data recorded at regular intervals
- Minimum Success
  - Record all the flight dynamics
  - Have the tensile specimen test activate
- Comprehensive Success
  - Record all the flight dynamics in an organized fashion through the whole flight
  - Activate the tensile specimen test at the correct time and collect all the data from it
WVU Tech-ATS: Expected Results

- We expect to find that the breaking force is similar to the test done on the ground.
- These values are expected to be slightly less, possibly even just 1%.
Off-Ramps

• An off-ramp in our design is the tensile test design.
  – Current Expected Design
    • The current design involves designing and apparatus that involves a small pulley system to apply the most true force possible to the tensile specimen and no moment
  – Off-Ramp Design
    • This design involves designing a device to hold the tensile specimen, while not worrying about moments that could happen during the test.
WVU Tech-ATS: Block Diagram

Pro Micro (5V)

Early Activation Switch T-180s

Voltage Booster

Power

Adafruit (5V)

HMC2003 (5V)

Linear Actuator (12V)

Voltage Regulator

Strain Gauge

Voltage Measuring Device

ADC

Open Log (3.35V)

Voltage Regulator (12V)

Voltage Regulator (12V)

 Voltage Regulator (12V)
WVU Tech-ATS: Electrical Schematic
WVU Tech ATS: Software Flow Diagram

Rocket Launch

- Does the timer activate? [Yes/No]
  - Yes: Microcontroller tells IMU to take readings
  - No: Continue to take readings

Continue to take readings

- Is the flight complete? [Yes/No]
  - Yes: Save final data to SD Card
  - No: Strain Gage determines stress readings at breaking point

Strain Gage determines stress readings at breaking point

- Does the tensile specimen break? [Yes/No]
  - Yes: Linear Actuator test runs
  - No: Has the rocket reached its peak?
    - Yes: Save final data to SD Card
    - No: Continue to take readings
Strain Gage Soda Can Experiment
- Found that strain came out to be $-500 \ \mu\text{Strain}$
- An average taken from other soda can experiments was found to be $-450 \ \mu\text{Strain}$
- Suggests slight error in its experimental setup,
- Most likely be attributed to the soda can itself

- For a 0.03 inch area ABS Plastic tensile specimen
- Expected Value for breaking force: $F \approx 173 \ \text{lb}$
• What was prototyped
  – Coding for the components of the sensor
  – Coding from the 2016 RSC launch is being modified to display readings that are easier to interpret

• Multiple tensile specimen models will be printed so that a breaking test can be performed on earth and in space
3.2 Subsystem Design
Structural Integration & Protection

Joel Lindsay
SIP: Isometric View – Zenith
SIP: Isometric View – Nadir
SIP: Top View - Payload Dimensions
SIP: Side View – Nadir Payload Dimensions

![Diagram of SIP Side View with dimensions](image)
SIP: Side View – Zenith Payload Dimensions
3.3 Subsystem Design
Power Distribution
Subsytem

Greg Lusk
PDS Overview

• Hardware required
  – Power distribution board
  – Atmel 328 chip
  – Hermetically sealed pass-through connector
  – Wiring harness and locking connectors
  – 2Ah, 3.7V Lithium cell battery

• Current issues
  – Selecting voltage regulators with sufficient current ratings for each channel
  – Ensuring the battery is not charged through circuitry
  – 4V, 5V, 12V, 24V, 28V raw power output channels
  – Finalized board layout dimensions: 3.0” x 4.125”
3.4 Subsystem Design
Data Acquisition

Greg Lusk
DAQ Overview

• Hardware required
  – Red Pitaya – main component of the DAQ subsystem
  – Hermetically sealed pass-through connector

• Current issues
  – Accumulating data via serial UARTs onboard DAQ and sending 16 bit data stream via parallel bus
  – Working through each subsystem requirement for telemetry and mapping the data out
  – Assigning each block of data a header and a footer
4.0 Risks

Steven Hard
Risks at PDR

Mission objectives are not met IF:
R1: WVU-APE.RSK.1 – Wireless communication link is not established between APE and ARP
R2: WVU-APE.RSK.3 – Damage occurs to ARP or other subsystems/components onboard during ejection
R3: WVU-IDA.RSK.1 – Connection between Rpis becomes broken/unplugged
R4: WVU-IDA.RSK.3 – ARC antenna fails to deploy
R5: WVU-SSD.RSK.1 – Bond wires on SSD are broken from handling and integration causing
R6: WVU-SSD.RSK.2 – MicroSD card vibrates loose on DAQ board
R7: MU-ATA.RSK.1 – Failure of servos to move mount
R8: WVSU-PVD.RSK.1 – Images can't be processed properly
R9: WVSU-PVD.RSK.2 – Ozone sensor overheats during descent
R10: WVSU-PVD.RSK.3 – Silicon Detectors damaged from radiation
R11: ATS-RSK.1 – Pieces may break off of the tensile specimen during the test causing damage other project
Risk Walk-Down

Mitigation Plan:
R1: WVU-APE.RSK.1 – Prototype comm setup / Test g-switch setup
R2: WVU-APE.RSK.3 – Use a spring that does not violently launch the CubeSat / Ensure the ejection trajectory clears all other structures and experiments
R3: WVU-IDA.RSK.1 – Stack raspberry pi connectors / Test power failure
R4: WVU-IDA.RSK.3 – Test antenna deployment setup extensively
R5: WVU-SSD.RSK.1 – Aluminum plate shielding / Sum detector pixels together so if bond wires on one breaks, still get usable data
R6: WVU-SSD.RSK.2 – RTV microSD card in place
R7: WVSU-PVD.RSK.1 – Test servo mount setup extensively
R8: WVSU-PVD.RSK.1 – Test for focal length limits and software reliability
R9: WVSU-PVD.RSK.2 – Test Ozone Sensor casing for heat resistance & capabilities
R10: WVSU-PVD.RSK.3 – Test silicon detectors for durability under heavy radiation
R11: ATS-RSK.1 – Building a containment unit or wall to keep pieces in a target area could reduce risk / Design enclosures for other sensitive components
New Risks

Mission objectives are not met IF:

R12: WVU-IDA.RSK.4 – View port is not large enough to provide adequate imaging profile
   - Redesign mounting of cameras
   - Off-ramp LWIR imager

R13: WVU-IDA.RSK.5 – ARC is not aligned with the ground station long enough to receive packets
   - Live with the risk

R14: WVU-SSD.RSK.3 – Testing schedule continues to slip due to delay in purchasing electron gun
   - Accelerate testing schedule once electron gun is delivered by increasing priority and dedicated man hours

R15: PDS.RSK.1 – Connecting the extra battery to the PDS allows the LiPo battery to be charged during operation
   - Design circuitry such that this is not electrically possible

R16: CDH.RSK.1 – Telemetry data packets are lost during transmission to ground and telemetry stream is thrown off
   - Assign heads and footers to each packet so breaks in packets can be distinguished more easily
5.0 Manufacturing Plan

Steven Hard
Mechanical Elements

• Manufactured parts
  – Payload Ejection Pod w/ support ribs & safety door for APE
  – PEP ejection tube & ejection cradle
  – 4.5”x2.5”x5” IDA enclosure w/ 4.47” dia opening for mounting optics port
  – Aluminum block to transfer heat from DAQ to main enclosure
  – Brackets and mounts for ATA
  – 3D printed brackets for VID and tensile specimen for ATS
  – Metal photodiode cube for PVD

• Procurements
  – Ejection Spring
  – Heat shield
  – SMA and DB-9 pass-through
  – 3”x3”x1.5” enclosure
  – 2.69” quartz optical port
  – Servos for ATA alt-az mount

• Schedule
  – Procure remaining items by end of Jan
  – Machine parts by early Feb
  – Full mockup mid Feb
Electrical Elements

• PCBs not yet complete
  – Finalizing a few electrical schematics
  – Soldering some early PCB fabriations

• Will likely do 1 PCB revision for each order
  – Incorporating accelerometer chip directly on board
  – Could cause some unforeseen errors or issues

• Procurements
  – Accelerometer for PEP
  – Wiring harness

• Schedule
  – Procure remaining items by end of Jan
  – Finalize PCBs by early Feb
  – Full mockup mid Feb
Software Elements

• Camera software is heritage
• IMU software is heritage
• Discrete blocks of code to be completed
  – All subsystem flight code developed and executed separately
• Which blocks depend on other blocks?
  – APE, ATA, PVD, & ATS code depends on DAQ code to package telemetry data
  – ARP depends on PEP to receive wireless data
  – ARC depends on IDA to send data via serial lines
  – ATS & APE depends on VID to gather visual fault info
• Schedule
  – Finalize software by end of Feb
6.0 Testing Plan

Steven Hard
Mechanical Testing

- **Subsystem level requirements to be verified**
  - Need an ejection system to launch probe into atmosphere
  - Communicate with tensile stress apparatus to activate it once it reaches the rocket’s peak
  - Alt-Az-Mount with 2 servos, a very small camera, a single-axis gyro, a real-time clock, and a raspberry pi to capture an astronomical target

- **Verification Tests**
  - Weight check – March
  - Fit check – March
  - Vibrations testing @ ATK Ballistics Lab – May
  - Subsystem testing – Feb
  - Deployment testing – Feb
    - PEP door deployment
    - ARP ejection
    - ATS actuation
Electrical Testing

• Subsystem level requirements to be verified
  – Need a data collection system to store the measurements (in-flight)
  – Must transmit probe data using wireless communication
  – Must sample data at 50 Hz or higher

• Verification Tests
  – Subsystem testing and file check – Dec
  – Benchtop and field testing comm systems – Jan

• Internally powered components
  – ARP will be tested with PEP deployment testing using Hall effect sensors and a G-switch to ensure unintentional deployment does not occur
  – PDS circuit designed and tested to ensure internal battery does not power or charge during powered flight
Software Testing

• Software dependencies
  – Sensor code development prior to full subsystem testing
  – Data logging and telemetry

• Verification Tests
  – Subsystem testing and file check – Dec
  – Benchtop & field testing comm systems – Jan
  – Full subsystem software/hardware testing – March
System Level Testing

• Subsystem level requirements to be verified
  – Must be 15 lbs
  – Must fit within the canister
  – Must survive launch
  – No voltage on deck

• Verification Tests
  – Weight check – March
  – Fit check – March
  – Voltage check – March
  – Vibrations testing @ ATK Ballistics Lab – June

• Integrated subsystems testing
  – Deployment testing – April
  – Timing/sequence testing – April
7.0 User Guide Compliance

Steven Hard
### User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; plane of plate?</td>
<td>???</td>
</tr>
<tr>
<td>Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs?</td>
<td>13.84 lb</td>
</tr>
<tr>
<td>Max Height &lt; 10.75&quot; (5.13”)</td>
<td>5.13”</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>YES</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>YES, see picture on slide 73</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>Using 5 lines</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>Yes</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>N/A</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
<td>YES, GSE 1 or GSE 2</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>YES, TE-1 and TE-2 or TE-R and TE-3</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>YES, TE-R</td>
</tr>
<tr>
<td>Using &lt; 1 Ah</td>
<td>No</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>200 V for Geiger (Will conformal coat)</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>YES, 928 MHz @ 250 mW TX power 435 MHz @ 500 mW TX power</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>YES</td>
</tr>
<tr>
<td>Whole team consists of US Persons</td>
<td>NO (All limitations understood)</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>NO</td>
</tr>
</tbody>
</table>
# User Guide Compliance: Power Interface

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power on T-180s</td>
</tr>
<tr>
<td>2</td>
<td>Pointing Signal</td>
</tr>
<tr>
<td>3</td>
<td>Pointing Signal</td>
</tr>
<tr>
<td>4</td>
<td>Pointing Signal</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
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<tr>
<td>8</td>
<td>GND</td>
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<tr>
<td>9</td>
<td></td>
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<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
### Telemetry Connector—WV-SPACE Side

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strain Gauge Measurement</td>
<td>20</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>Strain Gauge Measurement</td>
<td>21</td>
<td>Telemetry Stream</td>
</tr>
<tr>
<td>3</td>
<td>Strain Gauge Measurement</td>
<td>22</td>
<td>Telemetry Stream</td>
</tr>
<tr>
<td>4</td>
<td>Strain Gauge Measurement</td>
<td>23</td>
<td>Telemetry Stream</td>
</tr>
<tr>
<td>5</td>
<td>Strain Gauge Measurement</td>
<td>24</td>
<td>Telemetry Stream</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>25</td>
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8.0 Project Management Plan (PMP)

Steven Hard
### RS-X Fall 2016

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<tr>
<td>SFDC Kickoff Teleconferences</td>
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<tr>
<td>Team Tagup</td>
<td>9/12-9/16</td>
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<tr>
<td>SFDC General Update Teleconference</td>
<td>9/30</td>
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<td>Team CoDR Presentations</td>
<td>10/3-10/7</td>
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<tr>
<td>Team Tagup</td>
<td>10/17-11/21</td>
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<td>SFDC General Update Teleconference</td>
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<td>Team PDR Presentations</td>
<td>10/31-11/4</td>
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<td>RSX-17 Preliminary Design Review Teleconference</td>
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<tr>
<td>Team Tagups</td>
<td>11/14-11/18</td>
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<tr>
<td>RSX-17 Critical Design Review Teleconference</td>
<td>12/6</td>
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<tr>
<td>SFDC General Update Teleconference</td>
<td>12/9</td>
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Milestones

• Major Milestones
  • CDR (12/6/2016)
  • Prototype high risk items (12/20/2016)
  • Flight award announcement (1/16/2017)
  • Procure remaining components (1/18/2017)
  • Design PCBs (Week of 2/1/2017)
  • STR (Week of 2/15/2017)
  • ISTR (Week of 3/28/2017)
  • Receive payload deck (Week of 4/11/2017)
  • FMSR (Week of 5/2/2017)
  • LRR (Week of 7/20/2017)
  • Travel to Wallops (8/7/2017)
  • Launch (8/15/16)*
    – * Tentative, no guarantee – small chance launch could get cancelled due to weather or other unforeseen delays
## Budget

**WV RSX'17 Payload**

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<th>Supplier</th>
<th>Estimated, Specific Cost</th>
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<th>Total Cost</th>
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<tr>
<td>Supplies for payload construction</td>
<td>Various</td>
<td>$1,500.00</td>
<td>5</td>
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<td>Travel</td>
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<td>$12,950.00</td>
<td>7 Rooms @ 2 per room + fuel reimbursement</td>
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<td>Per Diem</td>
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<td>Registration</td>
<td>Space Grant</td>
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<td>$840.00</td>
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<td>Launch Charge</td>
<td>RockSat-X</td>
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<td>1</td>
<td>$14,000.00</td>
<td>3 installment payments</td>
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| Total (no margin):                        |               |                          |                 | $40,090.00  |
| Total (w/ margin):                        |               |                          |                 | $50,112.50  |

- Status of 1st installment – paid

---

**Margin**: 0.25  
**Budget**: $50,000.00  
**Last Update**: 11/7/2016
# Team Contact Matrix

<table>
<thead>
<tr>
<th>Institution</th>
<th>Team Member</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Person? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NASA IVV</strong></td>
<td>Steven Hard (Project Lead)</td>
<td><a href="mailto:Steven.L.Hard@nasa.gov">Steven.L.Hard@nasa.gov</a></td>
<td>304-367-8287</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Marcus Fisher (Chief Engineer)</td>
<td><a href="mailto:Marcus.S.Fisher@nasa.gov">Marcus.S.Fisher@nasa.gov</a></td>
<td>(304) 367-8337</td>
<td>Y</td>
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<tr>
<td><strong>WVU</strong></td>
<td>Greg Lusk (Advisor)</td>
<td><a href="mailto:gglusk@gmail.com">gglusk@gmail.com</a></td>
<td>304-293-0917</td>
<td>Y</td>
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<tr>
<td></td>
<td>Joel Lindsay (Integration Lead)</td>
<td><a href="mailto:jclindsay@mix.wvu.edu">jclindsay@mix.wvu.edu</a></td>
<td>304-276-4642</td>
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<tr>
<td></td>
<td>Sebastian Reger</td>
<td><a href="mailto:swreger@mix.wvu.edu">swreger@mix.wvu.edu</a></td>
<td>304-940-9125</td>
<td>Y</td>
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<tr>
<td><strong>WVUTech</strong></td>
<td>Farshid Zabihian (Advisor)</td>
<td><a href="mailto:Farshid.Zabihian@mail.wvu.edu">Farshid.Zabihian@mail.wvu.edu</a></td>
<td>304-442-3280</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Yadi Eslami (Advisor)</td>
<td><a href="mailto:Yadollah.EslamiAmirabadi@mail.wvu.edu">Yadollah.EslamiAmirabadi@mail.wvu.edu</a></td>
<td>304-442-3133</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Wade (Conrad) Lacey (Team Lead)</td>
<td><a href="mailto:wlacey@mix.wvu.edu">wlacey@mix.wvu.edu</a></td>
<td>907-947-0553</td>
<td>Y</td>
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<tr>
<td></td>
<td>Roger Targosky (Mechanical)</td>
<td><a href="mailto:rtargosky@mix.wvu.edu">rtargosky@mix.wvu.edu</a></td>
<td>304-312-7887</td>
<td>Y</td>
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<tr>
<td></td>
<td>William Prather (Software)</td>
<td><a href="mailto:whprather@mix.wvu.edu">whprather@mix.wvu.edu</a></td>
<td>304-989-9134</td>
<td>Y</td>
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<tr>
<td></td>
<td>Chris Alpeter</td>
<td><a href="mailto:csalpeter@mix.wvu.edu">csalpeter@mix.wvu.edu</a></td>
<td>(334)389-0096</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Marshall</strong></td>
<td>Jon Saken (Advisor)</td>
<td><a href="mailto:saken@marshall.edu">saken@marshall.edu</a></td>
<td>304-696-2753</td>
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<tr>
<td></td>
<td>Rae Stanley (Team Lead)</td>
<td><a href="mailto:raelashton1027@gmail.com">raelashton1027@gmail.com</a></td>
<td>304-840-8110</td>
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<tr>
<td></td>
<td>Jayden Leonard</td>
<td><a href="mailto:leonard57@marshall.edu">leonard57@marshall.edu</a></td>
<td>304-942-8973</td>
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<tr>
<td></td>
<td>Kayla O'Brien</td>
<td><a href="mailto:obrien44@marshall.edu">obrien44@marshall.edu</a></td>
<td>304-926-4946</td>
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<tr>
<td></td>
<td>Mayson Pine</td>
<td><a href="mailto:pine2@marshall.edu">pine2@marshall.edu</a></td>
<td>304-308-4375</td>
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<tr>
<td></td>
<td>Nick Zarilla</td>
<td><a href="mailto:nickzarilla@gmail.com">nickzarilla@gmail.com</a></td>
<td>304-690-0073</td>
<td>Y</td>
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<tr>
<td></td>
<td>Connor Henson (Software Lead)</td>
<td><a href="mailto:henson77@marshall.edu">henson77@marshall.edu</a></td>
<td>304-690-5743</td>
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<tr>
<td></td>
<td>Ryan Kingrey (Electrical Lead)</td>
<td><a href="mailto:kingrey4@marshall.edu">kingrey4@marshall.edu</a></td>
<td>606-465-4559</td>
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<tr>
<td></td>
<td>Dakota Studer (Mechanical Lead)</td>
<td><a href="mailto:studer3@live.marshall.edu">studer3@live.marshall.edu</a></td>
<td>304-305-3170</td>
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<tr>
<td></td>
<td>Derek Battise</td>
<td><a href="mailto:battise@live.marshall.edu">battise@live.marshall.edu</a></td>
<td>740-302-2347</td>
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<tr>
<td></td>
<td>Derek Staley</td>
<td><a href="mailto:staley28@live.marshall.edu">staley28@live.marshall.edu</a></td>
<td>304-615-6357</td>
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<tr>
<td></td>
<td>Jacob Staggs</td>
<td><a href="mailto:jacobstaggss22@gmail.com">jacobstaggss22@gmail.com</a></td>
<td>304-928-7958</td>
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<td>Taylor Lockhart</td>
<td><a href="mailto:lockhart39@marshall.edu">lockhart39@marshall.edu</a></td>
<td>304-417-8064</td>
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<tr>
<td><strong>WVSU</strong></td>
<td>Marek Krasnansky (Advisor)</td>
<td><a href="mailto:mkrasnansky@wvstateu.edu">mkrasnansky@wvstateu.edu</a></td>
<td>304-766-3257</td>
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<td>D.J. Smith (Team Lead)</td>
<td><a href="mailto:dsmith83@wvstateu.edu">dsmith83@wvstateu.edu</a></td>
<td>304-641-9224</td>
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<td>James Davis (Mechanical)</td>
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<td>Umer Rizwan (Electrical)</td>
<td><a href="mailto:urizwan@wvstateu.edu">urizwan@wvstateu.edu</a></td>
<td>304-807-3678</td>
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<td>Saira Rizwan (Software)</td>
<td><a href="mailto:srizwan@wvstateu.edu">srizwan@wvstateu.edu</a></td>
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<td>Caleb Eskins (GPS component)</td>
<td><a href="mailto:cmeskins@gmail.com">cmeskins@gmail.com</a></td>
<td>304-206-5673</td>
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<td>Justin Graham (Particle Detector)</td>
<td><a href="mailto:jgraham9@wvstateu.edu">jgraham9@wvstateu.edu</a></td>
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<td>Jacob Moore (Ozone Sensor)</td>
<td><a href="mailto:jmoore58@wvstateu.edu">jmoore58@wvstateu.edu</a></td>
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<td>Elijah Roberts (FMM)</td>
<td><a href="mailto:eelroberts5@wvstateu.edu">eelroberts5@wvstateu.edu</a></td>
<td>304-400-8688</td>
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## WV-SPACE

**CDR RS-X Team Availability Matrix**

**PLEASE USE MOUNTAIN TIME ZONE TIMES**

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<th>Thursday</th>
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<tr>
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Worries

• Fitting everything in
  – Need to get more detailed mechanical model

• DAQ & telemetry
  – Flush out serial connections and parallel bus
Conclusion

• Finalize prototyping of critical interfaces
• Continue with mitigation strategies for risk items
• Finalize finer details of design layout
• Finalize electrical schematics
• PCB design iterations
Backup Content

• Trade Studies
• Prototype Designs
• Prototype Layouts
• Supplementary Schematics
• Supplementary Software Diagrams
## WVU-IDA: Trade Studies

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<th>CPU</th>
<th>Raspberry Pi 3</th>
<th>Beaglebone Black</th>
<th>Jetson TK1</th>
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<tr>
<td><strong>Clock Speed</strong></td>
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<td>10</td>
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<td><strong>A/D Converters</strong></td>
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<td><strong>Programming Language</strong></td>
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<td><strong>Resources Available</strong></td>
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<td><strong>Average:</strong></td>
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### WVU-SSD: Trade Studies

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<td>Performance</td>
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<tr>
<td>Versatility</td>
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<td>6</td>
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<tr>
<td>Heritage</td>
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<tr>
<td><strong>Average:</strong></td>
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## WVSU-PVD: Trade Studies

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<th>Geiger Muller</th>
<th>Silicon</th>
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<td>Size:</td>
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<table>
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<tr>
<td>Versatility:</td>
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<tr>
<td>Memory:</td>
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| Average:       | **4.8**      | **7.5**      |
## WVU Tech ATS: Trade Studies

<table>
<thead>
<tr>
<th>IMU</th>
<th>Adafruit 10 DOF</th>
<th>ADIS16305</th>
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<tbody>
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<tr>
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<tr>
<td>Reliability</td>
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**Average:** 9.2 7.2

- The cost of the Adafruit is much cheaper and still reliable (also it is a 10DOF compared to the ADIS which is a 4DOF)
- With previous testing the Adafruit gives strong readings and is smaller which is easier to implement into a limited space
- For finding basic sensor information the Adafruit is a much better choice than the ADIS
WVU-APE: Prototype Design

• **Major Components:**
  – Spring ejection system, linear actuators, wireless RF modules, IMU, temp sensor, aerogel heatshield

• **Structure:**
  – Rectangular P-POD style launcher
  – CubeSat shaped probe

• **Major technology dependencies:**
  – Wireless comm with range > 1 mile
  – Heatshield with embedded temp sensor

• **Power and data needs**
  – 5V and 4 bits on parallel comm line
WVU-APE: Prototype Layout

Payload Ejection Pod

Atmospheric Probe

Arduino Microcontroller

RF Module
WVU-IDA: Prototype Design

• Major Components:
  – Raspberry Pi, Pi-cam, Pi No-IR cam, LWIR imager, HAM radio transceiver, Di-pole antenna

• Structure:
  – 2 board stack (4”x4”) in a separate sealed enclosure
  – Antenna board mounted in different location

• Major technology dependencies:
  – NIR wavelength: 800 – 2500 nm
  – LWIR wavelength: 8 to 14 μm

• Power and data needs
  – 5V and 32GB SD card
WVU-IDA Layout

- Imaging CPU
- LWIR Imager
- Transceiver
- RGB Camera
- NIR Camera
- Payload Camera
- Di-Pole Antenna
WVU-SSD: Prototype Design

• Major Components:
  – SSD, ADC, bias voltage supply, conditioning, particle shield

• Structure: what might this look like?
  – Rectangular board: 3

• Major technology dependencies: what kind of sensors will you need?
  – State-state detector sensitivity of > 1keV

• Power and data needs
  – +/- 7V with ~6W power consumption
  – >1MHz sample rate
WVU-SSD: Prototype Layout
WVU-SSD: Electrical Schematic

Analog conditioning circuitry schematic
MU-ATA: Prototype Design

• Structure
  • 2 rectangular boxes stacked on top of one another

• Major component
  • 2 servos
  • and the brackets and base
  • the camera
  • Raspberry Pi
  • Real-time Clock
WVSU-PVD: Prototype Design

• Major Components:
  – 1) Particle Detectors, 2) Ozone Sensor
  – 3) GPS Sensor, 4) 4DOF IMU
  – 5) Raspberry Pi Zero,
  – 6) F.M.M. + Camera + D.N.A.

• Structure:
  – Stack: Raspberry Pi 0 between two PCB’s.
WVSU-PVD: Prototype Design

• Major Technological Dependencies:
  • Particle Detectors:
    • Must be able to detect wavelengths gamma (100 keV), beta (0.1-1.2 MeV), and alpha (5-10 MeV).
  • Ozone:
    • Warm-up necessary for calibration
  • GPS:
    • Must acquire coordinates before takeoff
  • DNAE:
    • Thermal extremes, heat can destroy samples
  • IMU:
    • Record acceleration (x,y,z) & angular velocity in 3 dimensions using built-in gyroscope
WVSU-PVD: Prototype Layout
WVSU-PVD: Software Flow Diagram
All readings from the sensors will be taken in by the Raspberry Pi’s GPIO’s, each sensor needing it’s own.

**Geiger Counter Pseudocode:**

```c
// Conversion factor - CPM to uSV/h
//#define CONV_FACTOR 0.00812

void countPulse();

void setup() { pinMode(geiger_input, INPUT); digitalWrite(geiger_input,HIGH); attachInterrupt(2,countPulse, FALLING);

void loop() {
    detachInterrupt(x);
    countPerMinute = 6*count;
    radiationValue = countPerMinute * CONV_FACTOR;

    fprintf(stderr,"CPM=");
    fprintf(stderr,"%d\n",countPerMinute);
    fprintf(stderr,"%f\n",radiationValue);
    count = 0;
    attachInterrupt(2,countPulse,FALLING);
    delay(10000); }

void countPulse() { count++; }

int main () { setup();
    while(1) {
        loop();
        return (0); }
```
WVSU-PVD: Ozone Schematic

0 Pin = Analog

1 Pin = Digital
WVSU-PVD: GPS Schematic
WVSU-PVD: Particle Detector Schematic
WVSU-PVD: DNAE & IMU Schematic
WVSU-PVD: Geiger Counter Schematic
WVU Tech-ATS: Prototype Design

- The WVU Tech main board design will consist of:
  - Adafruit 10 DOF IMU
  - Strain Gage & INA125P Voltage Amplifier
  - Promicro Microcontroller
  - Openlog SD Card

- The WVU Tech side project will consist of:
  - FA-240-S-12-XX Linear Actuator
  - Rectangular Tensile Specimen (ABS Plastic)

- Structure: Constrained Envelope to hold Tensile Test
- Power needs: 4 pin power provider
WVUTech-ATS: Prototype Layout

- FA-240-S-12-XX Linear Actuator
- Adafruit 10 DOF IMU
- ProMicro Microcontroller
- INA125P Voltage Amplifier
- Strain Gage & INA125P Voltage Amplifier
- OpenLog SD Card

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