WV SPACE
Preliminary Design Review

WVU MU WVSU WVU-TECH FSU
NASA IV&V
Steven Hard, Rae Stanley, DJ Smith, Conrad Lacey, Greg Lusk, Marcus Fisher
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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.
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

• Benefits SmallSat community

• Enhance domain knowledge of next generation engineers & scientists
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
  – Determine if science apparatus is feasible for orbital mission
Theory and Concepts: Ejection & Heat of Re-entry

• Payload Ejection System
  – Hook’s Law
  – $F = K \times Dx$
  – 1.5 lbf

• Atmospheric Re-entry Probe
  – RF Comms
    • Expected range ~1mi
    • 2.4 GHz or 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 data from astronmetry.net and simple spherical trigonometry to target and identify stars
Theory & Concepts: ABS Yield Strength

• Theory
  - \( A_{\text{rectangle}} \times S_y = F \)
  - For a .025 inch area ABS Plastic tensile specimen
  - Known value for ABS Plastic: \( S_y \approx 5780 \text{ psi} \)
  - Expected Value for breaking force: \( F \approx 145 \text{ lb} \)

• 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**: $H = 0$ km ($T = 0$ min)
  - Begin data acquisition

- **Apogee**: $H = 115$ km ($T = 2.8$ min)
  - Timed Event 1

- **Telemetry OFF**: $H = 52$ km ($T = 0.6$ min)
  - End of Malamute Burn

- **Chute deploys**: $H = 10.5$ km ($T = 5.5$ min)
  - Timed Event 2

- **Splashdown**: $H = 0$ km ($T = 15$ min)

- **End of Malamute Burn**: $H = 0$ km ($T = -3$ min)
  - All systems on
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 ground station →

PVD collect O₃ levels →

Splash
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 Stress
- 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
## 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 and configurable to take video at 60 fps</td>
<td>Test</td>
<td>Coordinate w/ Wallops for pointing and software testing will determine if the frame rate is successfully reconfigured</td>
</tr>
<tr>
<td>ARC subsystem must be pointing nadir for at least 30 seconds after IDA experiment captures an LWIR image</td>
<td>Demonstrate</td>
<td>Coordinate w/ Wallops for pointing</td>
</tr>
<tr>
<td>APE experiment must be pointing nadir during ejection event and must not allow premature ejection to occur</td>
<td>Test</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>ATA must be pointing in the zenith direction for at least 30 seconds and must not reach outside the useable workspace of the alt-az mount</td>
<td>Test</td>
<td>Coordinate w/ Wallops for pointing and generate test cases for full range of motion for each DOF</td>
</tr>
</tbody>
</table>
## 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 viewport</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>
</tbody>
</table>
## 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>???</td>
</tr>
<tr>
<td>Max Height &lt; 10.75&quot; (5.13&quot;)</td>
<td>5.13&quot;</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/Yes</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>No/Yes</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>???</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>200 V (Will conformal coat)</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>YES, 2.4 GHz @ 60 mW TX power 435 MHz @ 500 mW TX power</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>YES, but speed is under 1 inch per second</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>
System Overview: Description of Partnership

• Partners:
  - West Virginia University Team
    - WVU-APE
    - WVU-IDA
    - WVU-SSD
  - Fairmont State University
    - FSU-ARP
  - 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
System Overview: Special Requests

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

• Extra Battery
  – Used to power O₃ and VID experiment after re-entry
  – Not yet sized/specified

• Payload ejection
3.0 Subsystem Design
WVU-Adaptable Payload Ejection

Steven Hard
WVU-APE: Mission Objective

- **Objective(s):**
  - Measure the dynamics of an ejective probe into microgravity and study its reentry dynamics

- **System Requirements**
  - Must measure data at 10 Hz or less
  - Need structure to support the instrument(s) in-flight
  - Need a data collection system to store the measurements (in-flight)
  - 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 System
  – 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: Block Diagram

PEP
- Xbee Rx
- Actuator
- 10DOF IMU

Raspberry Pi 3
- 32 GB uSD

ARP
- XBee Tx
- Temp Sensor
- 10DOF IMU
- Bat

G-switch

Serial

I2C

PDS

5V

24V
**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 Layout

Payload Ejection System

Atmospheric Probe

Arduino Microcontroller

RF Module
WVU-APE: Prototyping Plan

- What will you build/test between now and CDR to mitigate risks?

**Wireless communication**

**Risk/Concern**: Concerned about stability of comms with distance and rotations (Risk: objectives not met if wireless comm does not work)

**Action**: Prototype interface and verify stable communications with feasible range

**Payload Ejection**

**Risk/Concern**: Concerned about the size of spring to use for desired ejection dynamics

**Action**: Build prototype PEP and test various spring sizes

**Ejection Safety Mechanism**

**Risk/Concern**: Concerned that the payload ejection pod could launch prematurely

**Action**: Build a door that can hold the force of the spring on its own as a safety valve
WVU-APE: Software Design
3.0 Subsystem Design

WVU-Infrared Data Analysis

Steven Hard
WVU-IDA: Overview

• 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 @ 700 mA max current draw
  – Additional camera must be positioned to view necessary telemetry information and provided adequate lighting
  – Structures to support 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
- **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 & diagnostics (VID)** of probe ejection and any faults experienced during flight
  - LEDs, payload ejection, antenna deployment, structural failure
- **Expect to receive an IMU packet and LWIR image on the ground**
WVU-IDA: Block Diagram
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

Payload Camera

NIR Camera

Di-Pole Antenna
WVI-IDA: Prototyping Plan

**Risk/Concern**
- Ethernet connection has unstable behavior, so moving to GPIO connection (Risk jeopardize the mission objectives)

**Action**
- Prototype the GPIO signal solution to verify stable behavior

- NDVI Configuration
- LWIR Imager
- VID Microphone

**Risk/Concern**
- New component, need to get up to speed on how to use it

**Action**
- Build a test setup to image various heat sources

**Risk/Concern**
- Adding a mic may reduce processing performance (Risk degraded results)

**Action**
- Test camera running at full speed with microphone and verify video is still good
3.0 Subsystem Design
WVU-Solid State Detector

Greg Lusk
WVU-SSD: Mission Objective

- **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
  - High 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: Trade Studies

<table>
<thead>
<tr>
<th>CPU</th>
<th>Red Pitaya</th>
<th>Raspberry Pi 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Size</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Performance</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Versatility</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Heritage</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>40</strong></td>
<td><strong>37</strong></td>
</tr>
</tbody>
</table>
WVU-SSD: Block Diagram

Sealed Section

Timer provided by Wallops

Analog gain and conditioning

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

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

Exposed Section

28V

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

Charge/Voltage Amp

Solid State Detector

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WVU-SSD: Prototype Design

• Major Components:
  – SSD, ADC, bias voltage supply, conditioning, particle shield
• Structure: what might this look like?
  – Square board 4”x4”
• Major technology dependencies: what kind of sensors will you need?
  – State-state detector sensitivity of > 1keV
• Power and data needs
  – +/- 7V with ~4W power consumption
  – >1MHz sample rate
WVU-SSD: Prototyping Plan

- **SSD**
  - Risk/Concern: Confirm sensitivity & noise floor of SSD
  - Action: Test SSD using an electron gun and high quality DAQ instrumentation

- **COTS DAQ**
  - Risk/Concern: Flying a COTS DAQ solution to reduce risk of losing high $$$ DAQ instrument
  - Action: Prototype DAQ solution and test to verify performance is acceptable

- **Particle Shield**
  - Risk/Concern: Results will be skewed if ionized particles hit circuitry on SSD board
  - Action: Build metal sheet on top of the detector with square cutout to act as particle shield
WVU-SSD: Prototype Layout
WVU-SSD: Software Design

Start

Begin collecting data

Flag timed event signal "high"

Flag timed event signal "low"

Terminate program and shutdown

Exit
3.0 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

- **Minimum Success**
  - Minimum success will include a successful acquisition of one target and a tone or message from the payload indicating that the system has acquired and recorded data on the 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.
MU-ATA: Expected Results

This mission is a flight test / proof-of-concept experiment for an autonomous pointing determination and target acquisition system for astronomical instruments. A successful test will consist of:

1) determination of initial pointing from image data.
2) successful slew to nearest target.
3) obtaining image of the chosen target.
4) time permitting, acquisition and imaging of additional targets.

For this test a simple optical camera will be used to obtain images. However, the system is not dependent on any particular waveband.

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 will be in the range of 4-8 degrees, depending on bench tests of computation time for pointing determination.
• It has not yet been determined which camera(s) and servo(s) would be suitable for this project. Research for a suitable match for this project is ongoing, but there is not currently enough information to be able to perform a trade study.
This is a FBD for our electrical concept only. Not enough information has been gathered in order to complete a FBD for the entire system.
MU-ATA: Prototype Design

• What are the major components in your design prototype?
  – Structure: The structure is an alt-az-mount, which appears as two rectangular boxes on top of one another
  – Major technology dependencies:
    • Servos
    • Camera
    • RTC
    • Raspberry Pi
MU-ATA: Prototype Design
We are concerned that the component will be too big, or will not function correctly. Our entire project relies on this component.

Action:
3D print, and thoroughly test the prototype with multiple balloon launches.

We haven’t yet found a camera that is both small enough and has a good enough resolution.

Action:
Research cameras; buy the decided upon camera and test it with several test launches.
MU-ATA: Software Design

Define a function to activate the sensor for when the rocket has despun

Using if/then: If the rocket has despun then detect location
If rocket hasn't despun, repeat

If location is detected: then turn camera to target star

Define a function to take a picture and send it back.

If not in position: Repeat process until in position

Using a loop, repeat procedure for multiple stars. Use "until" gyro detected full spin.
3.0 Subsystem Design
WVSU-Particle Vectoring & DNA

Danford Smith
WVSU-PVD: Mission Overview

- **Objective:**
  - 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 (ppm) in Stratosphere & Troposphere on re-entry
  - **FMM:** Breaks in 6 kinds of DNA measured at & near apogee, with the amount of breaks increasing over time
WVSU-PVD: Mission Objective

- **Conceptual Success:**
  - **Particle Detector:** Alpha, Beta & Gamma Particles detected in 3-axes, the direction of radiation found.
  - **Ozone Sensor:** O$_3$ measured in (ppm) in Stratosphere & Troposphere on re-entry.
  - **GPS:** Direction tracked in 3D model during the launch & landing, testing limits at certain heights & velocities.
  - **IMU:** Angular Velocity & Acceleration measured in 3-axes.
  - **FMM:** Breaks in 6 kinds of DNA measured at & near apogee, with the amount of breaks increasing over time.
WVSU-PVD: Expected Results

- **Particle Detector**: ~300+ counts/second and direction.

- **Gas Sensor**: Between 5 and 25 milliPascals (mPa) through the troposphere & stratosphere.

- **IMU**: Flight dynamics comparable to those of the rocket's actual acceleration & angular velocity throughout the flight.

- **FMM ssDNA and dsDNA breaks**

- **GPS**: Acquiring real-time before launch, experimentally determining the limits of U.S.-based GPS modules.
WVSU-PVD: Block Diagram

- Particle Detector
- Geiger Counter
- Power
- Pi Zero
- FMM
- IMU
- GPS

Connections:
- 9V from Power to Particle Detector and Geiger Counter
- 5V from Power to Pi Zero and IMU
- 9600 Baud Rate from GPS to FMM

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WVSU-PVD: Prototype Design

- Orange – Pi Zero
- Black – IMU
- Red – FMM
- White – PCB
- Green – Gas Sensor
- Yellow – Particle Detectors
- Blue – GPS/Geiger Tube
WVSU-PVD: Prototype Design

- The State 2 is a stack, a Raspberry Pi Zero sandwiched between two PCBs
- One PCB is for Experiments & Sensors
- The other is for Circuitry & Essentials
- No experiment on the State 2 requires more than 9V
- Net current < 760mA
- All experiments on State 2 are controlled and connected to the Raspberry Pi Zero
Concerns about the consistency and verification of data since silicon detection is a relatively new method of particle detection.

Three circuits are going to be tested for consistency and reliability in data using available radiation sources. Results will be compared to Geiger Tube results.

Concerns over focus & clarity of images taken, differentiation of new breaks from old breaks, and amount of ram needed to process images.

The image processing software will be tested against controlled experiments of similar nature for consistency & predictability using available resources.
WVSU-PVD: Software Flow Diagram

Power on

Boot

FMM

GPS

IMU

Ozone Sensor

Particle Detector

Images from Camera

L1 = Li! Print Lc

No

Yes

t= interval

counter, \ t = 0

If signal = HIGH
Counter + = 1

No

Store Data

Repeat Loop
3.0 Subsystem Design
WVU Tech-ABS Tensile Stress

Conrad Lacey
WVUTech-ATS: Mission Overview

• Objectives:
  ➢ To build a circuit board to measure the flight dynamics of the rocket
  ➢ To create a device to complete a tensile specimen test while the rocket is at its peak

• System Requirements
  ➢ Devise a way to make our board communicate with our tensile specimen test to activate it once it reaches the rockets peak
  ➢ Have our data recorded at different intervals

• Minimum Success
  ➢ Record all the flight dynamics
  ➢ Have the tensile specimen test activate
WVUTech-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\%
WVUTech-ATS: Block Diagram
WVUTech-ATS: Prototype Design

• The WVU Tech board design will consist of:
  - Adafruit 10 DOF IMU
  - Strain Gage & INA125P Voltage Amplifier
  - 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 Design

FA-240-S-12-XX Linear Actuator

Adafruit 10 DOF IMU

ProMicro Microcontroller

Strain Gage & INA125P Voltage Amplifier

OpenLog SD Card
WVUTech-ATS: Software Flow Diagram

1. **Rocket Launches**
   - Does the timer activate?
     - Yes → Microcontroller tells IMU to take readings
     - No → Continue to take readings

2. **Linear Actuator test runs**
   - Has the rocket reached its peak?
     - Yes → Save final data to SD Card
     - No → Does the tensile specimen break?
       - Yes → Continue to take readings
       - No → Has the rocket reached its peak?

3. **Strain Gage**
   - Determines stress readings at breaking point
     - Yes → Does the tensile specimen break?
     - No → Continue to take readings

4. **Is the flight complete?**
   - Yes → Save final data to SD Card
   - No → Continue to take readings
WVUTech-ATS: Risk Walk Down

- **RSK.1**: Pieces may break off of the tensile specimen during the test and have a chance to damage other projects
  - Building a containment unit or wall to keep pieces in a target area could reduce risk
- **RSK.2**: Keeping the SD card safe during re-entry and the landing
  - Using telemetry to ensure data is received no matter what
- **RSK.3**: Keeping the wiring safe that connects the linear actuator to the microcontroller (they are separated compartments)
  - Designing some sort of plastic casing for the wiring could prevent potential damage to it during the launch
3.0 Subsystem Design
Structural Integration & Protection

Steven Hard
SIP: Isometric View
SIP: Top View Payload Dimensions
SIP: Side View Payload Dimensions
3.0 Subsystem Design
Data Acquisition

Steven Hard
C&DH Overview

• Hardware required
  – Red Pitaya – main component of the DAQ subsystem
  – Hermetic connector

• Current issues
  – Accumulating data and sending 16 bit data stream via parallel bus
4.0 Risks

Steven Hard
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: MU-ATA.RSK.1 – Failure of servos to move mount
R6: WVSU-PVD.RSK.1 – Images can't be processed properly
R7: WVSU-PVD.RSK.2 – Ozone sensor overheats during descent
R8: WVSU-PVD.RSK.3 – Silicon Detectors damaged from radiation
R9: ATS-RSK.1 – Pieces may break off of the tensile specimen during the test causing damage other project
Project Management Plan

Steven Hard
Organizational Chart

Steven Hard
Project Manager

Marcus Fisher
IVV Chief Engineer

Jon Saken
Marshall Advisor

Marek Krasnansky
WV State Advisor

Farshid Zabihiian
WVU Tech Advisor

John Kuhlman
WVU Advisor

Conrad Lacey
WVUTech Team
4 Students

Emily Certain
Deputy Project Manager

DJ Smith
WV State Team
4 Students

Rae Stanley
Marshall Team
7 Students

Greg Lusk
Electrical Engineer

Joel Lindsay
Mechanical Engineer

WVU Team
3 students
# 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>
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<tbody>
<tr>
<td>NASA IVV</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>
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<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>WVU</td>
<td>Greg Lusk (Advisor)</td>
<td><a href="mailto:grglusk@gmail.com">grglusk@gmail.com</a></td>
<td>304-293-0917</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>Julianne McIlvain (Team Lead)</td>
<td><a href="mailto:julianne.mcilvain@gmail.com">julianne.mcilvain@gmail.com</a></td>
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<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>
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<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>
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<tr>
<td></td>
<td>William Prather (Software)</td>
<td><a href="mailto:wprather@mix.wvu.edu">wprather@mix.wvu.edu</a></td>
<td>304-989-9134</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>
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<tr>
<td>WVUTech</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>
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<tr>
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<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>
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<tr>
<td></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>Marshall</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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<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>
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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:jacobstaggs22@gmail.com">jacobstaggs22@gmail.com</a></td>
<td>304-928-7958</td>
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<td></td>
<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>WVSU</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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<tr>
<td></td>
<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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<tr>
<td></td>
<td>James Davis (Mechanical)</td>
<td><a href="mailto:jdavisjr@wvstateu.edu">jdavisjr@wvstateu.edu</a></td>
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<tr>
<td></td>
<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>
<td>304-807-3678</td>
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## Schedule

### RS-X Fall 2016

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<tr>
<td>SFDC Kickoff Teleconferences</td>
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<td>Team Tagup</td>
<td>9/12-9/16</td>
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<tr>
<td>SFDC General Update Teleconference</td>
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<tr>
<td>Team CoDR Presentations</td>
<td>10/3-10/7</td>
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<tr>
<td>RSX-17 Conceptual Design Review Teleconference</td>
<td>10/12</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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<tr>
<td>RSX-17 Preliminary Design Review Teleconference</td>
<td>11/8</td>
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<tr>
<td>Team Tagups</td>
<td>11/14-11/18</td>
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<td>Team CDR Presentations @ NASA IV&amp;V Facility</td>
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<tr>
<td>RSX-17 Critical Design Review Teleconference</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 (11/20/2016)
  • 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**

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**WV RSX'17 Payload**

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<th>Estimated, Specific Cost</th>
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<th>Total Cost</th>
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<td>construction</td>
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<td>Travel</td>
<td>Space Grant</td>
<td>$1,850.00</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>$4,800.00</td>
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| Total (no margin):            |              | $40,090.00               |
| Total (w/ margin):            |              | $50,112.50               |
## WV-SPACE

**CoDR RS-X Team Availability Matrix**

**PLEASE USE MOUNTAIN TIME ZONE TIMES**

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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

• Begin prototyping critical interfaces and risk items
• Finalize design layout
• Generate electrical schematics
• Start looking at PCB design
Backup Content

• Trade Studies
## WVU-IDA: Trade Studies

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<thead>
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<th>CPU</th>
<th>Raspberry Pi 3</th>
<th>Beaglebone Black</th>
<th>Jetson TK1</th>
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## WVU-SSD: Trade Studies

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WVU Tech ATS: Trade Studies

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<th>IMU</th>
<th>Adafruit 10 DOF</th>
<th>ADIS16305</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Size</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Performance</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Versatility</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Reliability</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>9.2</strong></td>
<td><strong>7.2</strong></td>
</tr>
</tbody>
</table>

- 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