West Virginia University
Blue Team
Preliminary Design Review

10/29/2018

Presenters:
Austin Hodges, Aaron Ogle, James Stephens, Ethan Rohrbach, Clayton Cobb, Scott Yeatts, Amanda Cathreno, Jeff Bittinger, Derek Ross, Peyton Panger, Mohammed Altowaijri, Noah McDowell, Kaitie Stevens
PDR Presentation Contents

• Section 1: Mission Overview (Magnetic Field, Radiation, GPS, INS)
  – Mission Overview
  – Theory and Concepts
  – Expected Results
  – Success Criteria
  – Concept of Operations
  – Functional Requirements

• Section 2: System Overview
  – Subsystem Definitions
  – System Level Block Diagram
  – Critical Interfaces (ICDs)
  – Ports
  – User Guide Compliance
  – Sharing Logistics
PDR Presentation Contents

• Section 3: Subsystem Design
  – Subsystem A (SSA) - Magnetic Field and Radiation (MAGRAD)
    • SSA Block Diagrams
    • SSA Key Trade Studies
  – Subsystem B (SSB) - HackRF/INS
    • SSA Block Diagrams
    • SSA Key Trade Studies
  – Overall Risk for Subsystems A & B
    • Subsystem Risks/Mitigation
    • Risk Matrix for Overall Design
PDR Presentation Contents

• Section 4: Prototyping Plan
  – Items to be Prototyped (Magnetic Field, Radiation, GPS, INS)
  – Prototyping Plan (Overall)
  – Testing/Prototyping (Magnetic Field, Radiation, GPS, INS)

• Section 5: Project Management Plan
  – Org Chart
  – Schedule
  – Budget
  – Team Contact Matrix
  – Team Availability Matrix
Mission Overview

Austin Hodges
Mission Overview (overall)

• Mission statement
  – Team aims to measure different aspects of atmospheric phenomena to determine their complicity to accepted models, use Software Defined Radio (SDR) to record Radio frequencies during flight to determine feasibility of an SDR as a positioning system, and implement an Inertial Navigation System in conjunction with GPS to determine the flight path of the rocket.
Mission Overview: Radiation

James Stephens
Mission Overview

• Mission statement Breakdown
  – This instrument’s purpose is to determine the change in radiation throughout the flight and calculate an estimated altitude based on the radiation level encountered.
  – Expect to find a bell curve trend or similar over the whole flight

• Who will this benefit/what will your data be used for?
  – Data can be used to create another form of attitude estimation that compared to GPS data
Theory and Concepts - Overview

• Overview of concepts and theory
  – Relationship between radiation level and altitude (changes based on region of Earth you are near)
  – Viable use of this correlation to determine altitude
  – Accuracy of this method vs GPS
• What other research has been performed in the past?
  – Gamma radiation in the atmosphere has been observed in the past via both ground-based and space-based detectors such as BATSE and VERITAS.
  – Mostly used as a verification process for the relationship we have predicted between altitude and radiation.
Success Criteria

• Minimum Success Criteria:
  – Collect and store five minutes worth of radiation data, decode, and plot as function of time

• Comprehensive Success Criteria:
  – Collect and store radiation data for the entire duration of the flight, decode, plot as a function of time, and use to compare to GPS data and existing atmospheric radiation models as a means of determining position
Expected Results

• Expected Findings
  – As previously stated expect to find a bell curve trend or similar to following figure over the time of the whole flight
  – Expect to store data at about 5000 cpm and compare collected results with atmospheric models to look for accuracy
Radiation Atmospheric Model

- As altitude increases, radiation levels increase accordingly

Measured Parameters Plotted Against Time (Test Data)

Sensor begins recording

CPM
Time
μSv/hr

RockSat-C 2019
CoDR
Sample of Geiger Counter Test Data

<table>
<thead>
<tr>
<th>hour[h]</th>
<th>sec[s]</th>
<th>count</th>
<th>cpm</th>
<th>uSv/h</th>
<th>uSv/hError</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21.173</td>
<td>1</td>
<td>2.857</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>0</td>
<td>21.344</td>
<td>0</td>
<td>2.857</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>0</td>
<td>21.515</td>
<td>0</td>
<td>2.857</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>0</td>
<td>21.686</td>
<td>0</td>
<td>2.857</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>0</td>
<td>21.857</td>
<td>0</td>
<td>2.857</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>0</td>
<td>22.028</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>22.199</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>22.37</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>22.541</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>22.712</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>22.883</td>
<td>0</td>
<td>2.727</td>
<td>0.051</td>
<td>0.051</td>
</tr>
<tr>
<td>0</td>
<td>23.054</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>23.225</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>23.396</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>23.567</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>23.738</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>23.909</td>
<td>0</td>
<td>2.609</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>0</td>
<td>24.081</td>
<td>0</td>
<td>2.5</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>0</td>
<td>24.252</td>
<td>0</td>
<td>2.5</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>0</td>
<td>24.423</td>
<td>0</td>
<td>2.5</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>0</td>
<td>24.594</td>
<td>1</td>
<td>5</td>
<td>0.094</td>
<td>0.067</td>
</tr>
<tr>
<td>0</td>
<td>24.765</td>
<td>0</td>
<td>5</td>
<td>0.094</td>
<td>0.067</td>
</tr>
<tr>
<td>0</td>
<td>24.936</td>
<td>0</td>
<td>5</td>
<td>0.094</td>
<td>0.067</td>
</tr>
<tr>
<td>0</td>
<td>25.107</td>
<td>0</td>
<td>4.8</td>
<td>0.091</td>
<td>0.064</td>
</tr>
<tr>
<td>0</td>
<td>25.278</td>
<td>0</td>
<td>4.8</td>
<td>0.091</td>
<td>0.064</td>
</tr>
<tr>
<td>0</td>
<td>25.449</td>
<td>0</td>
<td>4.8</td>
<td>0.091</td>
<td>0.064</td>
</tr>
</tbody>
</table>
Mission Overview: Magnetometer

Ethan Rohrbach
Mission Overview

• Mission statement
  – Use a magnetometer to measure the Earth’s magnetic field, filtering out the effects of the rocket itself, to compare to accepted models of the flight region (World Magnetic NOAA models)

• Overall mission requirements
  – No ports needed
  – Stable magnetometer with internal and external interference calibrated out
Mission Overview

• What do you expect to discover or prove?
  – Expect to correlate with the accepted Earth magnetic field models (NOAA WMM) with a MLX90393 sensor.

• Who will this benefit/what will your data be used for?
  – Benefit anyone else debating whether or not a similar experiment is feasible. Also identifying an ideal magnetometer for a sounding rocket.
Theory and Concepts

• Theory
  – Earth is dipolar
  – Two poles, north and south
  – Magnetic field is produced from sources both above the surface and below the surface
  – With advancing technology, different spacecraft have been able to experiment with measuring and mapping Earth’s magnetic field
Theory and Concepts

• What other research has been performed in the past?
  – Fluctuation in field through Earth’s surface
  – Slowly became viable for direct field measurement rather than change in field
  – In 2013, Researchers measured the difference in field between the core, crust, mantle, and oceans.
Success Criteria

• Minimum Success Criteria:
  – To collect total field data representing the strength of the Earth’s magnetic field. Ranging $25\mu T - 60\mu T$.

• Comprehensive Success Criteria:
  – To obtain field strength and direction measurements which match the World Magnetic Model for our given coordinates and altitude.
Expected Results

- Expected Magnetometer Readings
  - North Component: $\sim 20\mu T$
  - East Component: $\sim -4\mu T$
  - Vertical Component: $\sim 43\mu T$
  - Total Field Magnitude: $\sim 47\mu T$
    - Based on WMM for coordinates at 115km altitude
Mission Overview- GPS

Kaitie Stevens
Mission Overview (GPS)

• Mission statement
  – To receive and save GPS band radio frequencies on a HackRF SDR for later comparison with the known flight GPS data to determine feasibility of an SDR as a positioning system

• Mission requirements
  – Multi-access port for shared GPS antenna
  – T-3 power access
Mission Overview (GPS)

• What do you expect to discover or prove?
  – If on a budget, SDR can act as a low cost GPS receiver

• Who will this benefit/what will your data be used for?
  – SDRs being implemented in complex electronic systems could be able to function as a GPS receiver in addition to a communications access for other instruments or systems
Theory and Concepts (GPS)

• Theory
  – GPS data is transmitted over the L frequency band
    • L1: 1,575.42 MHz
  – Transmitted by the 24 satellites in the GPS constellation arrangement
    • minimum of 4 satellites in view at any given time
  – SDR: Software Defined Radio uses software, rather than hardware as a means to receive/transmit radio waves
    • HackRF One can be set to only listen to a range of frequencies
Success Criteria (GPS)

• Minimum Success Criteria:
  – Record a minimum of 5 minutes of L-band radio waves via the SDR

• Comprehensive Success Criteria:
  – Record L-band data from T-3 seconds to splash down
  – The data recorded can be used to position the rocket within a mile radius
Expected Results (GPS)

- GPS radio frequency 1,575.42 MHz to be heard
- Positioning data will not be more accurate than the onboard GPS receiver
- Significant noise and possible RF interference
Mission Overview: INS

Aaron Ogle, Austin Hodges, & Derek Ross
The Charged Particle Density Project is being descoped for the following reason:

- High cost of parts without certainty of success
- Comlex design required custom parts that would be difficult to manufacture
- Project had large time requirements and was already behind schedule
Mission Overview (INS)

• Mission statement
  – To collect inertial measurements during flight to determine the position and attitude of the rocket in conjunction with Gold Team’s GPS

• Mission requirements
  – T-3 power access
Mission Overview (INS)

• What do you expect to discover or prove?
  – We expect to find the rocket’s flight path by combining INS and GPS measurements, as well as attitude determination for other sensors.

• Who will this benefit/what will your data be used for?
  – All other experiments will benefit from this experiment since altitude can be estimated with better accuracy using INS in conjunction with GPS
Theory and Concepts (INS)

• Theory
  – Inertial Navigation Systems (INS) use an Inertial Measurement Unit (IMU) to determine position
  – IMUs use 3 accelerometers arranged in 3 independent directions to find the acceleration in the x, y, and z directions as well as the orientation and roll, pitch, and yaw
  – The IMU data will be coupled with GPS data to find the flight path of the rocket
Design Overview (IMU)

- Currently, the ADIS 16405 IMU is being researched. Since we have experience with it:
  - Triaxial, digital gyroscope with digital range scaling
  - Enable external sample clock input up to 1.2 kHz
  - Tight orthogonal alignment, <0.05°
  - Triaxial, digital accelerometer, ±18 g
  - Triaxial, digital magnetometer, ±2.5 gauss

Image Reproduced from https://www.digikey.com/catalog/en/partgroup/adis16400-adis16405/20448?utm_adgroup=xGeneral&slid=&gclid=EAIaIQobChMIltIrvipCg3gIVHIGzCh0CvADyEAAYASAAEgLBx_D_BwE
Design Overview (MicroController)

• Currently, the NetBurner Mod 5213 is being considered
  – 32-bit 66 MHz processor
  – 32KB SDRAM and 256KB Flash
  – Industrial temperature range (−40°C to 85°C)
  – Customize with development kit

Image Reproduced from https://www.netburner.com/products/core-modules/mod5213
Design Overview (MicroController)

- Currently, the NetBurner Mod 54415 is being considered
  - 32-bit 250 MHz Processor
  - 64MB DDR2 RAM and 32MB Flash
  - Industrial temperature range (-40°C to 85°C)
  - MOD54417 can function as a switch or as two independent ports, each with its own MAC address
  - Customize with development kit

Image Reproduced from https://www.netburner.com/products/core-modules/mod5441x
Success Criteria (INS)

• Minimum Success Criteria:
  – Record IMU Data for least the time which it takes for the rocket to rise to apogee

• Comprehensive Success Criteria:
  – Record IMU Data during the entire flight time
Expected Results (INS)

• We expect to find acceleration and orientation during flight and integrate these measurements to find position given a known starting point

• By coupling the INS measurements with the Gold Team OEM GPS, better position estimates should be achieved
Example ConOps

Altitude

- **Radiation begins to increase appreciably**
  - $t \approx 1.3$ min
  - Altitude: 75 km

- **End of Orion Burn – Spin Rate Largest**
  - $t \approx 0.6$ min
  - Altitude: $\approx 115$ km

- **Apogee and Peak Radiation Levels**
  - $t \approx 2.8$ min
  - Altitude: $\approx 115$ km

- **T - 3 activation for GPS and INS to initialize**

- **G switch triggered**
  - All systems on
  - Begin data collection

- **t = 0 min**
- **Splash Down** $t \approx 15$ min

- **t $\approx 5.5$ min**
  - Chute Deploys
  - Most stable time to take data before splashdown

Altitude

End of Orion Burn – Spin Rate Largest

- **t $\approx 0.6$ min**
- Altitude: 52 km

Radiation begins to increase appreciably

- **t $\approx 1.3$ min**
- Altitude: 75 km

Apogee and Peak Radiation Levels

- **t $\approx 2.8$ min**
- Altitude: $\approx 115$ km

T - 3 activation for GPS and INS to initialize

- **t $\approx 5.5$ min**
  - Chute Deploys
  - Most stable time to take data before splashdown

**Example ConOps**

Altitude

- **Radiation begins to increase appreciably**
  - $t \approx 1.3$ min
  - Altitude: 75 km

- **End of Orion Burn – Spin Rate Largest**
  - $t \approx 0.6$ min
  - Altitude: 52 km

- **Apogee and Peak Radiation Levels**
  - $t \approx 2.8$ min
  - Altitude: $\approx 115$ km

- **T - 3 activation for GPS and INS to initialize**

- **G switch triggered**
  - All systems on
  - Begin data collection

- **t = 0 min**

- **Splash Down** $t \approx 15$ min

Altitude

- **Radiation begins to increase appreciably**
  - $t \approx 1.3$ min
  - Altitude: 75 km

- **End of Orion Burn – Spin Rate Largest**
  - $t \approx 0.6$ min
  - Altitude: 52 km

- **Apogee and Peak Radiation Levels**
  - $t \approx 2.8$ min
  - Altitude: $\approx 115$ km

- **T - 3 activation for GPS and INS to initialize**

- **G switch triggered**
  - All systems on
  - Begin data collection

- **t = 0 min**

- **Splash Down** $t \approx 15$ min

Altitude

- **Radiation begins to increase appreciably**
  - $t \approx 1.3$ min
  - Altitude: 75 km

- **End of Orion Burn – Spin Rate Largest**
  - $t \approx 0.6$ min
  - Altitude: 52 km

- **Apogee and Peak Radiation Levels**
  - $t \approx 2.8$ min
  - Altitude: $\approx 115$ km

- **T - 3 activation for GPS and INS to initialize**

- **G switch triggered**
  - All systems on
  - Begin data collection

- **t = 0 min**

- **Splash Down** $t \approx 15$ min
## Functional Requirements (Radiation):

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload shall be designed to withstand 25Gs of quasi-static loading in all</td>
<td>Analysis</td>
<td>The acceleration of the rocket will extreme and will demand a strong design which can withstand impulses of 50 Gs This means that all parts will have be securely fastened.</td>
</tr>
<tr>
<td>three axes with possible impulses of approximately 50 Gs in the Z axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the</td>
<td>Test</td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>RockSat-C program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td>Inspection</td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
## Functional Requirements (Magnetic Field):

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload shall be designed to withstand 25Gs of quasi-static loading in all three axes with possible impulses of approximately 50 Gs in the Z axis</td>
<td><strong>Analysis</strong></td>
<td>The acceleration of the rocket will extreme and will demand a strong design which can withstand impulses of 50 Gs. This means that all parts will have be securely fastened.</td>
</tr>
<tr>
<td>Magnetometer must take external and internal magnetic field contributions into account.</td>
<td><strong>Analysis &amp; Testing</strong></td>
<td>Within the payload, other instruments, power subsystem devices will produce RFI and magnetic fields which may interfere magnetic field measurements. Furthermore, magnetic field interference from sources which are external to the payload must be considered.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-C program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
## Functional Requirements (SDR):

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload shall be designed to withstand 25Gs of quasi-static loading in all three axes with possible impulses of approximately 50 Gs in the Z axis</td>
<td><strong>Analysis</strong></td>
<td>The acceleration of the rocket will extreme and will demand a strong design which can withstand impulses of 50 Gs. This means that all parts will have be securely fastened.</td>
</tr>
<tr>
<td>Antenna in multipurpose port must be internal and the exterior cover must be permeable to signals in the L frequency band</td>
<td><strong>Analysis</strong> &amp; <strong>Testing</strong></td>
<td>The antenna must be chosen according to its capabilities and size. Testing can performed with port covers of various materials to ensure its viability.</td>
</tr>
<tr>
<td>The system will receive the signal from a splitter connected to the antenna.</td>
<td><strong>Analysis</strong></td>
<td>The signals from the Antenna must be shared with Gold Team’s GPS.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-C program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
## Functional Requirements (INS):

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload shall be designed to withstand 25Gs of quasi-static loading in all three axes with possible impulses of approximately 50 Gs in the Z axis</td>
<td><strong>Analysis</strong></td>
<td>The acceleration of the rocket will extreme and will demand a strong design which can withstand impulses of 50 Gs. This means that all parts will have be securely fastened.</td>
</tr>
<tr>
<td><strong>INS shall be able to record at 25 Gs during flight and ideally 50 Gs during Flight.</strong></td>
<td><strong>Analysis &amp; Testing</strong></td>
<td>An IMU shall be selected which can ideally record 50 Gs during Flight so that the acceleration of the rocket can be measured throughout the entire flight.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-C program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
System Overview

Clayton Cobb, Peyton Panger, and Amanda Cathreno
High Level FBD of Subsystems
System Design – Physical Model Design in Canister
Hack RF, INS, and Geiger Counter

Geiger Counter

- Mass: 6.889g

Hack RF

- Mass: 226.79g

INS

- Mass: 48g
Magnetometer and RedBoard

Mass: 48g

Mass: 3.188g
Batteries

Approx Mass: 2267.96g
Design Overview: Activation Types

• Magnetic Field and Radiation will use either G-switch Activation or T-3 activation
• HackRF, GPS, and INS will use T-3 minute Activation
## RockSat-C 2018 User’s Guide Compliance Example

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can?</td>
<td>Current X and Y dimensions (minus battery) -0.0450in and 0.1570in respectively. Vertical center will depend on Gold Team collaboration and battery sizing</td>
</tr>
<tr>
<td>Contained in can</td>
<td>All hardware is small and will not protrude from can</td>
</tr>
<tr>
<td>Connected to can by 4/5 bulkheads on top and bottom only</td>
<td>No need for at this time</td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td>0.7646lb (will add battery weight and ballast)</td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td>Working with Gold Team to fit</td>
</tr>
<tr>
<td>No voltage on the can</td>
<td>As of now, nothing will be touching electronically</td>
</tr>
<tr>
<td>Activation wires at least 4 ft and Teflon coated</td>
<td>Will be completed</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>All wires used are at least 22 gauge</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>Approximate 0.5A, working to confirm</td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td>Not using</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Ideally Lithium Polymer, can change to NiMH if necessary</td>
</tr>
</tbody>
</table>
Design Overview: Shared Can Logistics

• Who are you sharing with?
  – We are sharing with WVU’s Gold Team who is implementing GPS via multipurpose port and an Optical Port and Camera

• Plan for collaboration
  – Our Mechanical teams will communicate their needs either via email or in person and collaborate to make the overall payload CAD

• Do you prefer mounting to the top or the bottom? Will you use a mid mounting plate?
  – We will use a custom Makrolon mounting plate

• Who needs what port?
  – Gold Team will be handling design of multipurpose port; we will use a signal splitter to harvest data for GPS and Hack RF
  – Gold Team will use the Optical Port
Subsystem Design

Magnetic Field and Radiation

James Stephens, Ethan Rohrbach, Peyton Panger, Clayton Cobb
EPS: Trade Studies (Radiation)

- Overall it became very apparent from the beginning that the Type 5 pocket geiger counter was the strongest and best available pick for the team.

<table>
<thead>
<tr>
<th>μController</th>
<th>Type 5</th>
<th>RADEYE G series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Availability</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>External Resources</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Compatibility with other instruments</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Access for data storage</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Average:</td>
<td>9.4</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Through a thorough trade study, it was obvious that the MLX90393 was the better choice for this experiment due to overall user friendliness, resolution, and many different specs.

<table>
<thead>
<tr>
<th>µController</th>
<th>MAG3110</th>
<th>MLX90393</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>User Friendliness</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Reliability</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Range</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Resolution</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Average:</td>
<td>6.8</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Subsystem Design
GPS and INS

Kaitie Stevens, Derek Ross, Austin Hodges, Clayton Cobb
EPS: Block Diagram (HackRF/INS)
EPS: Trade Studies (Hack RF)

- The Hack RF is a much more feasible option from both a cost and available resources perspective.

<table>
<thead>
<tr>
<th>µController</th>
<th>Hack RF</th>
<th>Signal Hound TG44A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Availability</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>External Resources</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Compatibility to other instruments</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Access for data storage</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>9.4</strong></td>
<td><strong>5.6</strong></td>
</tr>
</tbody>
</table>
Subsystem Design
Overall Risks

Austin Hodges, Clayton Cobb
EPS: Risks

• Risks
  1. EPS.RSK.1: Payload fails to activate due to power subsystem failure
  2. EPS.RSK.2: Data logger fails due to internal failure
  3. EPS.RSK.3: Instrument fails to activate due to microcontroller failure
  4. EPS.RSK.4: Structural Failure causes instruments to break or not record data

• How to Mitigate Risks
  1. Build and Test individual power subsystems, data logger systems, microcontrollers, and structure
  2. Combine all systems together into a single unit and test
  3. Perform analysis to make sure that these risks are accounted for
  4. Analyze structural components and perform stress analysis
# EPS: Risk Matrix

## Risk Analysis Matrix

<table>
<thead>
<tr>
<th>Impact</th>
<th>Probability</th>
<th>EPS. RSK.1</th>
<th>EPS. RSK.2</th>
<th>EPS. RSK.3</th>
<th>EPS. RSK.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Very Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Very Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Very Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Very Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negligible</td>
<td>Very Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. EPS.RSK.1: Payload fails to activate due to power subsystem failure
2. EPS.RSK.2: Data logger fails due to internal failure
3. EPS.RSK.3: Instrument fails to activate due to microcontroller failure
4. EPS.RSK.4: Structural Failure causes instruments to break or not record data
Test/Prototyping Plan

Kaitie Stevens, Clayton Cobb, Ethan Rohrbach, Michael Stephens, Scott Yeatts, Austin Hodges, Derek Ross
Prototyping Section (Magnetic Field)

• Magnetic Team
  – MLX90393 is our selected sensor
  – Prototyping has begun, new sensor will be tested using Sparkfun’s Qwiic Connect System
    • Testing will be done with Qwiic Shield and cables connecting sensor to the Redboard
    • On-board design will use a PCB to replace the Qwiic shield to secure any loose connections.
Prototyping Section (Radiation)

– Type 5 Pocket Geiger counter is the selected instrument
– Prototyping has begun, sensor will be tested using Sparkfun RedBoard and a manufacturer-provided Arduino sample sketch
  • Geiger counter is connected to RedBoard in accordance with manufacturer’s hookup guide
  • RedBoard is connected to laptop via manufacturer-provided connector cable and Arduino sketch is uploaded
  • Final on-board design will use a PCB to replace the jumper wires used currently to secure any loose connections.
Prototyping Section (GPS)

- **Hack RF**
  - **Current progress**
    - Data collection and processing with LabSat 3
    - Integration with Raspberry Pi
  - **Future progress**
    - Data collection and processing with Hack RF
    - Full integration with power, microcontroller, etc.
    - Mounting within canister
Prototyping Section (INS)

- INS
  - Current progress
    - Investigating the ADIS 16405 IMU which our group has access to and other possible choices with better Triaxial, digital accelerometer
  - Future progress
    - Acquire chosen microcontroller and pair with IMU and begin testing
Prototyping Plan

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

**Overheating**
- Concerned with antenna exposed in port being destroyed on re-entry
  - Action: Build and test heat shielding boxes out of various materials such as Fiberglass and Ceramics

**Elec. Interf.**
- With having so many sensors close to one another within the canister there will be interference
  - Action: Our hardware comes with calibration software that we can run once the canister is set up to filter this out

**Power Usage**
- Concern with what devices will be used in the Power Subsystem to achieve Power Requirements
  - Action: Design Power Subsystem for 12V, 5V, and 3.3V using linear voltage regulators and/or switching DC-DC Power Supply

**RF and Elec Shielding**
- High voltage and general electrical interference from the rocket will affect instrument readings and functionality
  - Action: Shielding boxes will be added to PCBs and our PSU can be adjusted to minimize its electrical interference
Testing/Prototyping (Radiation)

<table>
<thead>
<tr>
<th>Test</th>
<th>How</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation calibration</td>
<td>Place radioactive specimen on or near instrument</td>
<td>Determine accuracy of instrument</td>
</tr>
<tr>
<td>Pre Launch activation</td>
<td>Run a simulation of a pre launch experience with the Geiger counter</td>
<td>Ensure successful activation of Geiger counter on the launch date</td>
</tr>
<tr>
<td></td>
<td>activating prior to “take off”</td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>Using a vibration table at Wallops</td>
<td>Ensure that the payload can handle the vibrations of launch and re-entry.</td>
</tr>
</tbody>
</table>
# Testing/Prototyping (Magnetometer)

<table>
<thead>
<tr>
<th>Test</th>
<th>How</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial calibration</td>
<td>Use a compass to determine magnetic North</td>
<td>Determine accuracy of directional outputs</td>
</tr>
<tr>
<td>Interference calibration</td>
<td>Use magnets of known strength around the sensor while trying to measure Earth’s field</td>
<td>Simulate the interference that will be present during flight</td>
</tr>
<tr>
<td>Altitude testing/Data logging</td>
<td>Place sensor on weather balloon and record data on openlogger with SD card</td>
<td>A test flight with similar expected readings</td>
</tr>
</tbody>
</table>

Figure shows initial MLX90393 magnetic field readings in $\mu$T.
## Testing/Prototyping (GPS)

<table>
<thead>
<tr>
<th>Test</th>
<th>How</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truth Calibration</td>
<td>Take GPS data with LabSat3 and get truth location value with known working system</td>
<td>Give a baseline to compare our software developed system against</td>
</tr>
<tr>
<td>Play LabSat3 data into HackRF</td>
<td>Test Hack RF Software with data known to be good enough to determine GPS location</td>
<td>Confirm the HackRF’s ability to receive and record data</td>
</tr>
<tr>
<td>Record random data around campus directly into Hack RF</td>
<td>Test Hack RF to record data alone using an antenna</td>
<td>Confirm the HackRF’s ability to receive and record data from antenna</td>
</tr>
<tr>
<td>Remote start with Raspberry Pi</td>
<td>Setup HackRF to start recording data upon powering on</td>
<td>Confirm Raspberry Pi will power on and begin recording data on startup</td>
</tr>
<tr>
<td>Test timed power on with sim. T-3 activation</td>
<td>Have timer system to power on when reaches certain count</td>
<td>To confirm that the Raspberry Pi can handle this type of activation.</td>
</tr>
<tr>
<td>Test</td>
<td>How</td>
<td>Purpose</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Truth Calibration</td>
<td>Calibrate IMU to initial position and measure change in position on ground.</td>
<td>Test the system and determine possible sources of error.</td>
</tr>
<tr>
<td>Measure the Position</td>
<td>Verify the position, velocity, and acceleration measurements, as well as attitude on the ground</td>
<td>Confirm the IMU’s ability to measure acceleration and attitude</td>
</tr>
<tr>
<td>Remote start with Microcontroller</td>
<td>Setup IMU with Microcontroller to start recording data upon powering on</td>
<td>Confirm Microcontroller will power on and begin recording data on startup</td>
</tr>
<tr>
<td>Flight test</td>
<td>Place IMU on a weather balloon in an attempt to measure flight path</td>
<td>Simulate mission environment</td>
</tr>
<tr>
<td>Test timed power on with sim. T-3 activation</td>
<td>Have timer system to power on when reaches certain count</td>
<td>To confirm that the Microcontroller can handle this type of activation.</td>
</tr>
</tbody>
</table>
Project Management Plan

Austin Hodges
Organization Chart

Principal Investigator/ Project Manager (PI/PM)
Austin Hodges

Project Systems Engineer (PSE)
Clayton Cobb

Radiation

Instrument Lead (IL)
James Stephens

Mechanical Engineer (ME)
Peyton Panger

Command and Data Handling (C&DH)
Jeff Bittinger

Flight Software (FSW)
Mohammed Altowaijri

Magnetic Field

Instrument Lead (IL)
Ethan Rohrbach

Mechanical Engineer (ME)
Peyton Panger

Command and Data Handling (C&DH)
Jeff Bittinger

Flight Software (FSW)
Derek Ross

Flight Software (FSW)
Noah McDowell

GPS

Instrument Lead (IL)
Kaitie Stevens

Mechanical Engineer (ME)
Amanda Cathreno

Command and Data Handling (C&DH)
Scott Yeatts

Flight Software (FSW)
Mohammed Altowaijri

Flight Software (FSW)
Noah McDowell

INS

Instrument Lead (IL)
VACANT

Mechanical Engineer (ME)
Amanda Cathreno

Command and Data Handling (C&DH)
Scott Yeatts & Aaron Ogle

Flight Software (FSW)
Derek Ross

Flight Software (FSW)
Noah McDowell
### Preliminary Semester Schedule

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>EXACT DATES</th>
<th>PLAN START</th>
<th>PLAN DURATION</th>
<th>ACTUAL START</th>
<th>ACTUAL DURATION</th>
<th>PERCENT COMPLETE</th>
<th>MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(CoDR) Teleconference</td>
<td>10/8-12/2018</td>
<td>10</td>
<td>0.5</td>
<td>10</td>
<td>0.5</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Test Building</td>
<td>10/9/2018-12/1/2018</td>
<td>10</td>
<td>2.5</td>
<td>10</td>
<td>2.5</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Earnest Payment of $1,000 Due</td>
<td>10/12/2018</td>
<td>10</td>
<td>0.5</td>
<td>10</td>
<td>0.5</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Sketch of Systems</td>
<td>10/12/2018-11/15</td>
<td>10.5</td>
<td>1.5</td>
<td>10.5</td>
<td>1.5</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Design Review (PDR)</td>
<td>10/29-11/2/2018</td>
<td>10</td>
<td>1.5</td>
<td>10</td>
<td>1.5</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Review (CDR) Teleconference</td>
<td>12/3-7/2018</td>
<td>11</td>
<td>2</td>
<td>11.5</td>
<td>1.5</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>
## Budget

<table>
<thead>
<tr>
<th>Budget Items</th>
<th>Cost</th>
<th>Budget Items</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Budget</td>
<td>$15,000.00</td>
<td>INS</td>
<td>$800.00</td>
</tr>
<tr>
<td>Canister Cost</td>
<td>$6,000.00</td>
<td>Mechanical</td>
<td>$250.00</td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>$100.00</td>
<td>Miscellaneous</td>
<td>$500.00</td>
</tr>
<tr>
<td>Radiation</td>
<td>$300.00</td>
<td>Cost of Trip</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>HackRF</td>
<td>$1,000.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Current Amnt. Remaining | $2,550.00 |
Team Contact and Potential Changes

- Our Mentor is Jason Gross of WVU.
- All team members have access to a Google Team Drive.
- The team communicates via email, Slack, text, and GroupMe.
- There may be some changes to the some specifics, but the overall design should remain consistent.
# Contact Matrix

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Email</th>
<th>Phone #</th>
<th>US Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin Hodges</td>
<td>PI/PM</td>
<td><a href="mailto:amhodges@mix.wvu.edu">amhodges@mix.wvu.edu</a></td>
<td>302-542-3457</td>
<td>Yes</td>
</tr>
<tr>
<td>James Stephens</td>
<td>IL</td>
<td><a href="mailto:mjstephens@mix.wvu.edu">mjstephens@mix.wvu.edu</a></td>
<td>703-389-1393</td>
<td>Yes</td>
</tr>
<tr>
<td>Clayton Cobb</td>
<td>PSE</td>
<td><a href="mailto:crc0028@mix.wvu.edu">crc0028@mix.wvu.edu</a></td>
<td>816-509-6113</td>
<td>Yes</td>
</tr>
<tr>
<td>Amanda Cathreno</td>
<td>ME</td>
<td><a href="mailto:ajcathreno@mix.wvu.edu">ajcathreno@mix.wvu.edu</a></td>
<td>304-826-7677</td>
<td>Yes</td>
</tr>
<tr>
<td>Derek Ross</td>
<td>FSW</td>
<td><a href="mailto:dwross@mix.wvu.edu">dwross@mix.wvu.edu</a></td>
<td>717-881-6470</td>
<td>Yes</td>
</tr>
<tr>
<td>Peyton Panger</td>
<td>ME</td>
<td><a href="mailto:pepanger@mix.wvu.edu">pepanger@mix.wvu.edu</a></td>
<td>304-382-2723</td>
<td>Yes</td>
</tr>
<tr>
<td>Jeff Bittinger</td>
<td>C&amp;DH</td>
<td><a href="mailto:jtb0010@mix.wvu.edu">jtb0010@mix.wvu.edu</a></td>
<td>301-268-6353</td>
<td>Yes</td>
</tr>
<tr>
<td>Scott Yeatts</td>
<td>C&amp;DH</td>
<td><a href="mailto:sgyeatts@mix.wvu.edu">sgyeatts@mix.wvu.edu</a></td>
<td>804-240-3364</td>
<td>Yes</td>
</tr>
<tr>
<td>Ethan Rohrbach</td>
<td>IL</td>
<td><a href="mailto:etrohrbach@mix.wvu.edu">etrohrbach@mix.wvu.edu</a></td>
<td>330-241-3939</td>
<td>Yes</td>
</tr>
<tr>
<td>Aaron Ogle</td>
<td>IL</td>
<td><a href="mailto:atogle@mix.wvu.edu">atogle@mix.wvu.edu</a></td>
<td>304-380-5434</td>
<td>Yes</td>
</tr>
<tr>
<td>Mohammed Altowaijri</td>
<td>FSW</td>
<td><a href="mailto:Msaltowaijri@mix.wvu.edu">Msaltowaijri@mix.wvu.edu</a></td>
<td>304-413-3215</td>
<td>No</td>
</tr>
<tr>
<td>Noah McDowell</td>
<td>FSW</td>
<td><a href="mailto:nmmcdowell@mix.wvu.edu">nmmcdowell@mix.wvu.edu</a></td>
<td>(681) 209-1014</td>
<td>Yes</td>
</tr>
<tr>
<td>Katie Stevens</td>
<td>IL</td>
<td><a href="mailto:aistevens@mix.wvu.edu">aistevens@mix.wvu.edu</a></td>
<td>304-676-5595</td>
<td>Yes</td>
</tr>
</tbody>
</table>
# Team Availability Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
<td>7:30-8:40 best of best</td>
<td>7:30-8:40 best of best</td>
<td>7:30-8:40 best of best</td>
<td>7:30-8:40 best of best</td>
<td></td>
</tr>
<tr>
<td>8:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**
- **Best Time**: Yes
- **Yes**: Yes
- **No**: No

---

RockSat-C 2019
CoDR
Worries

- RF Interference from Power Subsystem will likely affect all of the instruments to some level; GPS and Magnetic Field are particularly vulnerable
- Minimize this by creating shielding boxes for the GPS and the Power Subsystem to protect against RFI
Conclusion

• Complete Preliminary Testing by CDR
• Start to evaluate and implement analytic ways to address significant sources of error for instruments by CDR
• Start to implement RFI Shielding and account for RF Interference in instrument measurements by CDR
Gold Team
Preliminary Design Review

West Virginia University
Logan Sheridan, Karie Winston, Ellis Johnson, Josh Jones, Joe Fisher, Nick Swiney, Aly Augsberger, Adri Persad, Joseph Graves, Rocco Bisciglolia, Junaid Karim, Yusif Razzaq, Shivani Karlapati

Mentor: Dr. Jason Gross

10/30/18
PDR Presentation Contents

• Section 1: Mission Overview
  – Mission Overview
  – Theory and Concepts
  – Mission Requirements
  – Expected Results
  – Concept of Operations

• Section 2: System Overview
  – Subsystem Definitions
  – System Level Block Diagram
  – Critical Interfaces (ICDs)
  – Ports
  – Sharing Logistics
PDR Presentation Contents

• Section 3: Subsystem Design
  – Subsystem - GPS
    • GPS Block Diagram
    • GPS Key Trade Studies
    • Subsystem Risks/Mitigation
  – Subsystem - Optics
    • Optics Block Diagram
    • Optics Key Trade Studies
    • Subsystem Risks/Mitigation
PDR Presentation Contents

• Section 4: Prototyping Plan
  – GPS Prototype
  – Camera Prototypes

• Section 5: Project Management Plan
  – Organizational Chart
  – Schedule
  – Budget
  – Team Contact Matrix
  – Team Availability Matrix
Mission Overview

Joe Fisher, Ellis Johnson
Mission Overview: Gold Team

“The goal of our mission is to use on-board videography to gauge the accuracy of coastal matching by comparing calculated position from collected images to the measured GPS position.”

- Two primary experiments: GPS Tracking and Coastal Matching
  - Subteam assigned to each experiment
- Expectation is to calculate rocket telemetry (Coastal matching) and compare results to tracked telemetry results (GPS)
- Quantify validity of coastal matching as a means of rocket telemetry tracking
GPS Mission Overview

Joe Fisher
Mission Overview: GPS Tracking

• Objective: Acquire and log accurate positioning and time data from satellites through onboard GPS system
• System Requirements:
  – GPS antenna and receiver to capture pseudoranges and correctly measure position
  – Rigid mounting for the GPS system
  – Wiring connections from antenna to receiver to data acquisition device
• Minimum Success
  – Acquire pseudorange data packets from GPS for a portion of the flight to allow for post-processing and comparison to optical tracking results
Mission Overview: Theory and Concepts (GPS)

- GPS antenna acquires simultaneous signals from multiple satellites (at least 4)
- Signal feeds from antenna to receiver where it is converted to loggable data
- Data stored in external storage device and can be processed post-flight
- Conversion software and coding used to gather position and time data from collected data packets
- Past experiences: GPS tracking tested in several previous RockSat experiments
  - Moderate success in collecting and post-processing position and time data
Coastal Matching

Ellis Johnson
Mission Overview: Coastal Tracking

- **Objective**: Capture images during flight to allow for coastal matching to be performed post-flight
- **System Requirements**:
  - A camera that captures images everytime the coastline comes into view of the port
  - A mount that will keep the camera steady enough to minimize motion blur in-flight
  - Either an internal or external method of data storage (dependent on camera)
  - Software able to process images to allow for coastal tracking post-flight
- **Minimum Success**
  - Successful image capture during Terrier burn and prior to splashdown while spin rate is low
Mission Overview: Theory and Concepts (Optics)

- T-3 switch activation - camera begins recording until splashdown (controlled by software coding)
- Video stored on a microSD
- Specific frames of coastline taken from video for coastal tracking
- Frames of coastline turned into monochrome images
- Geographical information system (GIS) used: Google Earth
- Matlab code used to triangulate the position of the rocket from captured images and GIS data with respect to time
  - Position compared with GPS position
Expected Results & ConOps

Logan Sheridan
Mission Overview: Expected Results

- Expect to gather pseudorange data from GPS
  - Data to be post-processed through conversion of file format to yield numerical positioning values

- Expect to acquire images of the coastline during the flight
  - Acquired images of coastline will be cross compared to the GIS to track the trajectory of the rocket
  - Coastal Matching error ±200m
  - Images captured during minimum success criteria will allow for smaller scale error testing
Mission Overview: Theory and Concepts (Optics)

Things to be aware of:

- In 2016, West Virginia University conducted an experiment with multiple cameras.
  - Two cameras failed due to script errors
    - One of the cameras failed at the startup.
  - Two other cameras achieved a video that recorded approximately twenty minutes of the flight, which monitored the various internal experiments from launch to splashdown.
- Through the various cameras throughout the entire canister multiple errors in other experiments were monitored such as:
  - No power to their experiment even though lights indicated there was power. This was then ruled to be a voltage regulator malfunction.
Gold Team ConOps

- **T-3 switch**
- All systems on
- Begin GPS and camera data collection

**t = -3 min**

**Apogee**
- $t \approx 2.8 \text{ min}$
- Altitude: $\approx 115 \text{ km}$

**End of Orion Burn – Spin Rate Largest**
- $t \approx 0.6 \text{ min}$
- Altitude: 52 km

**t = -3 min**

**High tumble rate**
- $t \approx 4 \text{ min}$
- Altitude: $\approx 95 \text{ km}$

**t = 15 min**

Splashdown, GPS and camera shut down

**Low spin**
- $t \approx 5.5 \text{ min}$
- Chute Deploys
Functional & Design Requirements:

• GPS data recording
  – Powered on with T-3
    • Pre-flight powered on time allows for proper satellite position retrieval
  – GPS System shall be ground tested before flight to practice data collection and post-processing

• Video recording
  – Powered on with T-3 switch
  – Looking into GoPro Software (Start recording on power up)
  – Camera Calibration
## Functional Requirements Verification:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera records when electrical system is powered on</td>
<td>Test</td>
<td>The camera will be connected to the electrical system after a software analysis to confirm functionality on power on.</td>
</tr>
<tr>
<td>GPS records when electrical system is powered on</td>
<td>Test</td>
<td>GPS will be connected to electrical system and tested when powered on.</td>
</tr>
<tr>
<td>The full system shall fit on a single RockSat-C deck</td>
<td>Inspection</td>
<td>Visual inspection will verify this requirement.</td>
</tr>
<tr>
<td>The camera shall be able to record at desirable resolution and spin rate</td>
<td>Test</td>
<td>The system will be subjected to additional rate table tests.</td>
</tr>
<tr>
<td>The full system shall weigh within the range of 19.8 to 20.2 lbs.</td>
<td>Inspection</td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
System Overview

Nick Swiney, Aly Augsberger
System Definitions

• Camera Subsystem
  - Composed of camera of choice connected to a circuit board which will be linked to a microcontroller

• GPS Subsystem
  • PCB: Printed Circuit Board
  • GPS: Global Positioning System
  • EMI: Electromagnetic interference
  • RFI: Radio Frequency Interference
Design Overview: Ports

• Dual SMA Multipurpose Port
  – Will be used to house patch antenna for GPS receiver
• Optical Port
  – We will be modifying the cover for camera
• Give a plan for proper interfacing between port and payload
  – Data collection for GoPro is internal
  – Switch to activate the GoPro
System Level Block Diagram
Camera Mount

GoPro Mount

GoPro Camera
Camera and Mount Dimensions
GPS Antenna mounted in Multipurpose Port

Multipurpose Port  GPS Antenna Housing  GPS Antenna
Multipurpose Port Dimensions
GPS Antenna and Housing Dimensions
PCB Layout

PCB Cover

PCB Approximate Volume
PCB and PCB Shell Dimensions
Shelf Layout

- Multipurpose Port with GPS Antenna
- Battery
- PCB/Cover
- Camera/Mount
Battery Dimensions
Canister with Optical Port
## Rule Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass at 10±0.1lbs</td>
<td>0.375 lb (mass of GoPro and NovAtel)</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>1 Watt (NovAtel)</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Nickel-Metal Hydride</td>
</tr>
</tbody>
</table>

- Complete
- Incomplete/Subject to Change
- Not Started
Design Overview: Shared Can Logistics

• Blue Team Mission Statement:
  – “Team aims to measure different aspects of atmospheric phenomena to determine their complicity to accepted models, use Software Defined Radio (SDR) to record Radio frequencies during flight, and implement an Inertial Navigation System in conjunction with GPS to determine the flight path of the rocket.”

• Collaboration: We will be designing a custom mid-mount in collaboration with the Blue Team.
• Since we are in the same class, collaboration is very simple
• Gold team will handle antenna and blue team will handle the splitter, with research beginning immediately
De-Scopes & Off-Ramps

- If our GoPro is not able to receive adequate images for GEO tracking
  - Thorlabs Camera available to use
    - Thorlabs Camera will require more interface familiarization

- We will have multiple PCB’s available in case some burn out in testing.
- If GPS system shows issues, there is plenty of room in the budget to purchase other instruments.
Subsystem Design

GPS

Adri Persad
GPS: Block Diagram
GPS: Trade Studies

<table>
<thead>
<tr>
<th>GPS Receiver</th>
<th>Weight</th>
<th>Novatel</th>
<th>Telemetrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10%</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Resources Available</td>
<td>20%</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Weight</td>
<td>10%</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Size</td>
<td>10%</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Collective Experience</td>
<td>30%</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>20%</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Total Score (out of Ten):</td>
<td></td>
<td>9.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>

- Similar scoring in size and weight considerations
- The Novatel receiver had two perfect scores. There was wealth of information to be found about Novatel receivers, and the collective experience was ten since our mentor was familiar with their operation.
- Telemetrum is cheaper, but both are priced reasonably
- Telemetrum only rated to 31 km altitude
GPS: Risk Matrix

- The horizontal represents the likelihood of a risk, the vertical is the corresponding consequence.

GPS.RSK.1: Accurate positioning data cannot be obtained IF significant EMI / RFI is present in the canister
GPS.RSK.2: Data logging objective will not be met IF system fails to power on properly
GPS.RSK.3: Data logging objective or function of GPS will not be met IF software fails
GPS: Risk Mitigation

• GPS.RSK.1: Reducing the effects of EMI / RFI
  - Consider incorporating RF chokes
  - Consider incorporating Faraday cage / RF shielding to isolate systems
  - Consider using a linear voltage regulator instead of a switching power supply

• GPS.RSK.2: Ensuring the system powers on properly
  - Testing the system before flight to gain confidence in its ability to boot multiple times
  - Consider using a microcontroller instead of PC base hardware

• GPS.RSK.3: Ensuring the software runs correctly
  - Testing and debugging the code before flight to gain confidence in its ability to control the software
Subsystem Design
Coastal Matching

Joshua Jones
Coastal Tracking: Block Diagram
EPS: Trade Studies

- Max FPS, weight, and ease of use are the highest priorities for optics
- Max FPS has a positive correlation with shutter speed, and a higher shutter speed is needed to reduce motion blur

<table>
<thead>
<tr>
<th>Camera</th>
<th>GoPro</th>
<th>Thorlabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Max FPS</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Res @ Max FPS</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Weight</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Ease of Use/Compatibility</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Average:</td>
<td>7.6</td>
<td>7.4</td>
</tr>
</tbody>
</table>

- Weight directly occupies part of the weight budget
- Ease of use and compatibility affect the possibility of component failure
- The higher resolution pictures of the GoPro will offer clearer coastline information than the Thorlabs camera
OPTICs: Risk Matrix

<table>
<thead>
<tr>
<th>OPT.RSK.1</th>
<th>OPT.RSK.2</th>
<th>OPT.RSK.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPT.RSK.4</td>
<td>OPT.RSK.1</td>
<td>OPT.RSK.3</td>
</tr>
<tr>
<td>OPT.RSK.5</td>
<td>OPT.RSK.4</td>
<td>OPT.RSK.5</td>
</tr>
</tbody>
</table>

OPT.RSK.1: Accurate coastal tracking application cannot be applied IF motion blur make coastlines unable to be mapped

OPT.RSK.2: Failure to collect data IF camera doesn’t start recording with T-3 switch

OPT.RSK.3: Corruption of data during splashdown IF the SD card isn’t protected

OPT.RSK.4: Useable images will not be captured IF spin rate and/or altitude is too high

OPT.RSK.5: Useable images will not be captured IF sufficient light is not available or clouds cover coastline
Optics: Risk Mitigation

- **OPT.RSK.1**: High motion blur
  - Maximize FPS (GoPro 240 @ 1080p, TL 258 @ 1280x1024)
  - Proper mounting to minimize vibration of camera
- **OPT.RSK.2**: Camera recording after activation switch
  - Microcontroller failsafe test for data output
  - Well tested activation software
- **OPT.RSK.3**: Loss of data on splashdown
  - Data stored on a few different microSD cards
  - Waterproofed storage location
- **OPT.RSK.4**: Unuseable images from spin rate/altitude
  - Perform tests on camera with varying frame rates using rate table
  - Perform horizon testing on camera
- **OPT.RSK.5**: Unuseable images from visibility issues
  - Prepare and test celestial tracking
Test/Prototyping Plan

Karie Winston
Prototyping Section (GPS)

- GPS prototyping will mainly consist of our prototype data logging PCB.
  - Several boards may need to be made.

- GPS table top experiment should be running by CDR. Our goal with this is to show we can collect, log, and interpret GPS data.
Prototyping Section (Optics)

• Camera prototyping is minimal for GoPro camera.
  – Camera comes with internal memory.
  – Rate Table testing should confirm if it can handle rotation and drop testing will be necessary to make sure GoPro doesn’t cut out at 25g’s.

• CMOS Camera will require some prototyping.
  – Data logging PCB will have to be built and tested.
  – Camera will have to be tested with multiple fps and resolution settings to determine what’s best.

• Both cameras will be subject to rate table testing to determine if the fps/resolution can handle spin rate.
  – We will use horizon tracking to mimic our coastal tracking
Prototyping Plan

**Risk/Concern**

- Mounting GPS Receiver and data logger PCB’s is a concern. Also building and soldering our PCB’s will take time.

**Action**

- Building a table top experiment with similar mounts and boards will allow us to test and see how our experiment operates as a whole.

- Obtain optical port specs. Build prototype and set rate table test. Use horizon tracking to see if coastal tracking is feasible at max spin.

**GPS**

**OPTICS**

- How the camera will interface/mount with the optics port. Also, will our camera’s be able to handle the spin rate of the orion burn.
Project Management Plan

Logan Sheridan
Organizational Chart

Faculty Advisor
Dr. Jason Gross

Project Manager
Logan Sheridan

Instrument Lead
Adri Persad

C&DH
Joseph Graves IV

Software
Shivani Karlapati

Mechanical Engineering
Nick Swiney

Optics Team

Project Systems Engineer
Karie Winston

Instrument Lead
Ellis Johnson

C&DH
Junaid Karim

Software
Rocco Biscieglia

Software
Yusif Razzaq

Mechanical Engineering
Aly Augsberger

GPS Team

Instrument Lead
Joe Fisher

Instrument Lead
Ellis Johnson

Instrument Lead
Josh Jones
<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Phone Number</th>
<th>US citizen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logan Sheridan</td>
<td><a href="mailto:pls0013@mix.wvu.edu">pls0013@mix.wvu.edu</a></td>
<td>813-365-0759</td>
<td>Y</td>
</tr>
<tr>
<td>Karie Winston</td>
<td><a href="mailto:klwinston@mix.wvu.edu">klwinston@mix.wvu.edu</a></td>
<td>705-509-0994</td>
<td>Y</td>
</tr>
<tr>
<td>Ellis Johnson</td>
<td><a href="mailto:egjohnson1@mix.wvu.edu">egjohnson1@mix.wvu.edu</a></td>
<td>304-406-8365</td>
<td>Y</td>
</tr>
<tr>
<td>Joshua Jones</td>
<td><a href="mailto:jsjones2@mix.wvu.edu">jsjones2@mix.wvu.edu</a></td>
<td>419-266-0800</td>
<td>Y</td>
</tr>
<tr>
<td>Adri Persad</td>
<td><a href="mailto:ampersad@mix.wvu.edu">ampersad@mix.wvu.edu</a></td>
<td>304-240-8163</td>
<td>Y</td>
</tr>
<tr>
<td>Joe Fisher</td>
<td><a href="mailto:jrfisher@mix.wvu.edu">jrfisher@mix.wvu.edu</a></td>
<td>412-527-7541</td>
<td>Y</td>
</tr>
<tr>
<td>Aly Augsberger</td>
<td><a href="mailto:aaaugsberger@mix.wvu.edu">aaaugsberger@mix.wvu.edu</a></td>
<td>540-455-5954</td>
<td>Y</td>
</tr>
<tr>
<td>Joseph Graves IV</td>
<td><a href="mailto:jagraves@mix.wvu.edu">jagraves@mix.wvu.edu</a></td>
<td>304-960-0166</td>
<td>Y</td>
</tr>
<tr>
<td>Nick Swiney</td>
<td><a href="mailto:nwswiney@mix.wvu.edu">nwswiney@mix.wvu.edu</a></td>
<td>540-292-4938</td>
<td>Y</td>
</tr>
<tr>
<td>Junaid Karim</td>
<td><a href="mailto:jbkarim@mix.wvu.edu">jbkarim@mix.wvu.edu</a></td>
<td>703-577-6613</td>
<td>Y</td>
</tr>
<tr>
<td>Rocco Biscieglia</td>
<td><a href="mailto:rhbiscieglia@mix.wvu.edu">rhbiscieglia@mix.wvu.edu</a></td>
<td>302-373-9536</td>
<td>Y</td>
</tr>
<tr>
<td>Yusif Razzaq</td>
<td><a href="mailto:yr0001@mix.wvu.edu">yr0001@mix.wvu.edu</a></td>
<td>304-534-0853</td>
<td>Y</td>
</tr>
<tr>
<td>Shivani Karlapati</td>
<td><a href="mailto:jskarlapati@mix.wvu.edu">jskarlapati@mix.wvu.edu</a></td>
<td>703-507-4268</td>
<td>Y</td>
</tr>
</tbody>
</table>
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Estimated, Specific Cost</th>
<th>Number Required</th>
<th>Total Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMOS Camera</td>
<td>Thor Labs</td>
<td>$365.65</td>
<td>1</td>
<td>$365.65</td>
<td>Programmable</td>
</tr>
<tr>
<td>CMOS Lens</td>
<td>Thor Labs</td>
<td>$200.00</td>
<td>1</td>
<td>$200.00</td>
<td>Lens determinant on port</td>
</tr>
<tr>
<td>GoPro</td>
<td>GoPro</td>
<td>$325.00</td>
<td>1</td>
<td>$325.00</td>
<td>Hi fps/resolution</td>
</tr>
<tr>
<td>OEM 615 GPS Receiver</td>
<td>Novatel/Already Owned</td>
<td>$0.00</td>
<td>0</td>
<td>$0.00</td>
<td>Already owned</td>
</tr>
<tr>
<td>Printed Circuit Boards</td>
<td>Advanced Circuits</td>
<td>$33.00</td>
<td>4-5</td>
<td>$100.00</td>
<td>4-5 board revs, depending on burnouts</td>
</tr>
<tr>
<td>Misc. Electronics/Batteries</td>
<td>DigiKey/amazon</td>
<td>$150.00</td>
<td>1</td>
<td>$150.00</td>
<td>Variable, Depending on Batteries</td>
</tr>
<tr>
<td>SD Cards</td>
<td>amazon.com</td>
<td>$20.00</td>
<td>2</td>
<td>$40.00</td>
<td>1 Card per instrument</td>
</tr>
<tr>
<td>Data Logger</td>
<td>Sparkfun.com</td>
<td>$15.00</td>
<td>2</td>
<td>$30.00</td>
<td>1 Logger per instrument</td>
</tr>
</tbody>
</table>

**Total (no margin):** $1210.655

**Total (w/ margin):** $1513.32

---

**Monetary Contributions**

_all come from WVU MAE department_
# Team Availability

**West Virginia University**

**Fall 2018 RS-C Team Availability Matrix**

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
<td></td>
<td>7:30-8:40 best</td>
<td></td>
<td>7:30-8:40 best</td>
<td></td>
</tr>
<tr>
<td>8:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:00 PM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:00 PM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**

- **Best Time**: Yes
- **Not Available**: No

**Example**

- Monday: No
- Tuesday: Yes
- Wednesday: Yes
- Thursday: Yes
- Friday: No
Worries and Concerns

• Rocket Spin rate at and after Orion burn. Will camera be able to take sufficient video?
• Optical Port - Will camera fit? What are the specs for the port?
• GPS - Will GPS have sufficient battery power?
• GPS - Data logger surviving splash down
• Our main actions following up to the CDR are as follow:
  – Rate table testing, to determine if FPS and resolution are upstanding.
  – GPS table-top testing. Have a working prototype that can perform properly.
  – Detailed CAD showing CoG and weight properties.
  – Complete Wiring Diagrams; as well as at least one prototype PCB for each experiment