RockSat-X @Virginia Tech
Preliminary Design Review

Virginia Tech
John Mulvaney, Ethan Ohriner, Marcus Wanner
11/2/2016
PDR Presentation Content

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  – Theory and Concepts
  – Concept of Operations
  – Expected Results
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PDR Presentation Content

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PDR Presentation Contents

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  – Radio

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PDR Presentation Contents

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1.0 Mission Overview
Mission Overview: Mission Statement

- Mission Statement:
  - Receive ADS-B and AIS transmissions in order to demonstrate the compatibility of a software defined radio (SDR) on different communication frequencies.

- ADS-B and AIS will replace radar tracking of aircraft and boats, offers a more flexible and efficient system.
  - ADS-B will be implemented on the Iridium NEXT constellation to begin the shift from radar to radio tracking.
  - FAA shift to implementation of ADS-B tracking is a “near certainty”

- This technology can increase the interoperability of satellite communications and enable a low cost ($15K) C2 RF transceiver for Class D missions
Mission Overview: Mission Objectives

• Modify an existing software defined radio unit to survive the expected loads of launch and reentry

• Complete detailed testing and launch operations using an advanced modular ground station.

• Successfully receive information via ADS-B and AIS signals on-board the payload and transmit plane/boat data to ground station via the amateur band.

• Demonstrate success of omni-directional antenna.
Mission Overview: Theory and Concepts

- Small satellites are becoming more and more prevalent in industry - all need tracking/communication capability.

- The government would like to avoid CubeSats overcrowding their communications networks.

- ADS-B and AIS allow for improved tracking of sea and airways.
  - The Iridium NEXT constellation is planning on incorporating ADS-B tracking for air traffic efficiency, illustrating the industry need.
1. **Launch**
   Telemetry/GPS begins
2. **Launch to Apogee**
   Telemetry/GPS continues
   Collection of temp/pressure data
3. **Apogee**
   - Nose cone separation
   - Skin separation
   - De-spin to TBD rate
   - Telemetry/GPS continues
   - ADS-B and AIS tracking signals collected and stored.
   - Signal received from ground station telling to switch from ADS-B to AIS.
   - Data transmitted to ground station
4. **Descent**
   Telemetry/GPS continues
5. **Chute Deploy**
   Telemetry/GPS continues
6. **Landing**
   Telemetry/GPS terminates
   Payloads recovered
Mission Overview: Expected Results

• Successful acquisition of aircraft/boat data via ADS-B and AIS signals via dipole antennas (stored on payload and transmitted using RS232 as redundancy).
  – Position, speed, course, and identification

• Successful communication between the spacecraft and ground station.
Mission Overview: Success Criteria

Minimum Success Criteria:
– Collection of ADS-B or AIS signals and transmitted via SDR, RS-232, or on-board data collection.

Comprehensive Success Criteria:
– Constant collection of ADS-B and AIS signals, transmitted to the Virginia Tech ground station via SDR and patch antenna.
– Structural integrity maintained through reentry and splashdown
2.0 System Overview
System Overview: Science Design Overview

- **Instruments**
  - PicoZED (SDR): 2x2 receive and transmit paths in the 70 MHz to 6.0 GHz range.
  - Patch and Dipole Antenna

- Payload will receive ADS-B and AIS transmissions via the dipole antennae

- Ground station will receive ADS-B, AIS, and housekeeping data from the payload

- Payload will receive a signal from the ground station to switch between transmitting ADS-B and AIS
  - SD card used to store data locally
  - Data will be telemetered through rocket telemetry
  - Housekeeping data will be telemetrized over payload radio intermittently

- Payload and ground station will record transmit/receive commands and protocol changes
System Overview: Engineering Design Overview

• Structures
  – Heritage housing protects payload from space environment, reentry, and splashdown
  – Structure will be designed to protect sensitive electronics from launch and reentry loads
  – Dipole Antenna deployment using spring system and nichrome wire
  – Static S-band and L-band Patch antennas

• Power
  – Electronics will be powered by rocket batteries

• Electric
  – Software defined radio platform - PicoZed
  – 5W S-Band power amplifier (9-15 V, 1.4A)
  – Heritage local data storage with SD card
  – Heritage Nichrome wire deployment mechanism
  – Heritage housekeeping sensors (temperature, pressure, coarse/fine acceleration)

• Software must be developed to handle data, switch protocols, process transmit/receive commands
### Top Level Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
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<tr>
<td>The payload SDR module shall receive and transmit AIS / ADS-B signals</td>
<td><strong>Test</strong></td>
<td>Testing will be conducted on the East coast and in Blacksburg to ensure data collection on both protocols.</td>
</tr>
<tr>
<td>The patch antennas shall have the required radiative properties to communicate with ground stations</td>
<td><strong>Test</strong></td>
<td>We will test the dB and waveform from the patch antennas using anechoic chamber.</td>
</tr>
<tr>
<td>The full system shall fit on a single RockSat-X deck</td>
<td><strong>Inspection</strong></td>
<td>Visual inspection will verify this requirement.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-X program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
</tbody>
</table>
System Overview: Functional Block Diagram
System Overview: Description of Partnerships

- **Orbital-ATK**
  - Orbital ATK is interested in SDR compatibility with cubesats
  - Bi-weekly meetings to assist with radio research and other questions regarding the project
  - We are responsible for design and mechanical/electrical integration
  - Orbital ATK will provide select components that will be needed for this project (PicoZed)

- **a.i. solutions**
  - a.i. solutions has been a consistent partner with RockSat-X at Virginia Tech since 2014 payload
  - Bi-weekly meetings to assist with mechanical design and offer general payload advice
System Overview: User’s Guide Compliance

- Mass estimate - will not exceed constraint
- No expectation of exceeding allotted space
- Antenna deployment (2 dipole antenna)
- Expect to use Asynchronous lines at 19200 baud
- Expect to use GES-1, TR-A, TR-B
- CG requirement will be met
- RF - will be transmitting and receiving
- Pointing request (See next slide)
- Expect to use four 10 F, 2.4 V capacitors in thermal knife circuit (heritage RockSat circuit)
- All team members US citizens
System Overview: Pointing Request

Blacksburg
3.0 Subsystem Design
Subsytem Design: Structures

- Heritage waterproof housing with electrical feedthrough

- Weight
  - Weight Estimate around 10lbs
  - Ballast will be added to reach a total of 15lbs

- Hardware required
  - 2 Patch Antenna arrays (4 total)
  - 2 dipole deployment assemblies
    • Spring loaded, folding (see following slides)

- No Current Issues with Structural Design
Subsystem Design: CAD Model

![CAD Model Image]
Subsystem Design: CAD Model
Subsystem Design: Dipole Antenna Deployer
Subsystem Design: Electrical

- **Power**: All components are within the mission’s power constraints.

- **Mass**: Arduino, Fine/Coarse Accelerometers, Pressure sensor, Temperature Sensor, Various DC/DC converters, AIS/ADS-B antenna deployers, Power amplifier, 3 Preamps

- **Subteam risks**:  
  - Unfamiliarity with the Picozed - potential issues getting it to communicate properly with RS232, Arduino, and other radio

- **Next steps**:  
  - Breadboard and test all sensors  
  - Program Arduino to format and store data on data logger
Subsystem Design: Electrical - Thermal Knife

This is the signal input to the circuit. 0V (GND) to this charges the capacitor and 5V cuts off the charging power supply and discharges the capacitor through the thermal knife.

N-Channel Mosfet
(Actually DMG3420U Fet)

AP9465GEM
M3

R3
1

Thermal Knife
(about 1 Ohm)

C1
10

10 Farad super-capacitor stores the energy to fire the thermal knife

P-Channel Mosfet
(Actually DMG3415U Fet)

FDS6975

R2
10k

R1
120

12V power source for charging super-cap

Voltage divider to drop 12V to 2.4V to charge the super-cap
Subsystem Design: Electrical - Thermal Knife
### Subsystem Design: Electrical - Power Budget

<table>
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<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Start Time (min)</th>
<th>On Time (min)</th>
<th>Watts</th>
<th>Ah</th>
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<tbody>
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<td>Arduino</td>
<td>9</td>
<td>0.1</td>
<td>-180</td>
<td>8.03</td>
<td>0.9</td>
<td>0.01</td>
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<tr>
<td>Instruments</td>
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<td>-180</td>
<td>8.03</td>
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<td>0.01</td>
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<td>Payload Ettus</td>
<td>9</td>
<td>0.2</td>
<td>0</td>
<td>5.6</td>
<td>5.6</td>
<td>0.02</td>
</tr>
<tr>
<td>CMD Ettus</td>
<td>9</td>
<td>0.2</td>
<td>0</td>
<td>5.6</td>
<td>5.6</td>
<td>0.02</td>
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<tr>
<td>AIS Deployer</td>
<td>12</td>
<td>~0.05</td>
<td>?</td>
<td>?</td>
<td>0.6</td>
<td>0.013</td>
</tr>
<tr>
<td>ADS-B Deployer</td>
<td>12</td>
<td>~0.05</td>
<td>?</td>
<td>?</td>
<td>0.6</td>
<td>0.013</td>
</tr>
<tr>
<td>Power Amp</td>
<td>9-15</td>
<td>1.4</td>
<td>0</td>
<td>5.6</td>
<td>16.8</td>
<td>0.131</td>
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<tr>
<td>Preamps (x3)</td>
<td>12</td>
<td>0.12 (x3)</td>
<td>0</td>
<td>5.6</td>
<td>1.44</td>
<td>0.034</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
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<td></td>
<td>0.251</td>
<td></td>
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<tr>
<td><strong>Below Limit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.249</td>
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</table>

- Total Watts: 0.251
- Below Limit: 0.249
Subsystem Design: Software

• Intend to use same housekeeping software for arduino as 2016 payload

• GNU radio software to be developed with assistance from HUME Center

• Some concern over using GNU radio with PicoZed, see risks below
Subsystem Design: Radio Subteam

- **Power:** Two radios which will consume 0.02Ah, one 5W Power amplifier which will consume 0.131 Ah, three pre-amp filters which consumer 0.034 Ah total

- **Mass:** Two radios, two arrays of patch antennas, two dipole antenna assemblies

- **Subteam risks:** Hardware selection, radio link budget (see Seth, Zach, ‘16 docs to resolve, Zach is currently developing).

- **Next steps:** Procure BladeRF for software development
Risk Matrix

Risk 1: ADS-B/AIS not collected IF dipole antenna deployment fails
Risk 2: Non-mechanical failed transmission from SDR
Risk 3: Water/Heat Damage after apogee
Risk 4: SDR components fail during launch
  - Possibility listed as 2 as PicoZed SDR has not been tested
4.0 Test/Prototyping Plan
Test/Prototyping Plan

1. Test radio and antenna designs by receiving broadcasts from Virginia Tech ground station over desired frequencies, as well as via transmitting from radio to Virginia Tech ground station over desired frequencies.

2. Test Arduino communication to PicoZed radio through serial USB link

3. Begin testing AIS and ADS-B reception via dipole antennas. ADS-B collection at Virginia Tech, AIS collection at Virginia Beach

4. Confirm sensors/data logger/Arduino connection by breadboarding the sensors and Arduino and utilizing last years software to read and compute the data.

5. Test transmission of data from PicoZed to ground station as well as from the ground station to the PicoZed radio.

6. Test all payload components after building and vibe testing payload.
Test/Prototyping Plan - Structures

1. 3D CAD model design of payload components
   - Deployable dipole antenna
   - Patch antenna mounting
   - Waterproof housing - internal arrangement and design

2. Prototype deployable antenna using 3D printer, CNC machine, and machine shop tools.

3. Testing/validation of deployable antennas and static patch antenna mounts
   - Vibration testing potentially using Orbital-ATK resources

4. Final machining of parts; build payload

5. Final testing and integration at NASA Wallops
5.0 Project Management Plan (PMP)
Management: Team Organization

Team Mentors
Zach Leffke
Eric Petrosky

Faculty Advisor:
Dr. Kevin Shinpaugh
kashin@vbi.vt.edu
Dr. Jonathan Black
jonathan.black@vt.edu

Team Sponsors
Virginia Tech SEC
Orbital ATK
a.i. solutions

Team Leaders:
Ethan Ohriner
ethano95@vt.edu
John Mulvaney
Johnwm1@vt.edu

Radio
Marcus Wanner
Sagar Govani
Johnny Jaffee

Computer/Electric
Tony Defilippis
Ramy Armanous
Nick Miller
Emma Manchester

Mechanical
Nick Corbin
Karl Vitale
Austin Hannon
Ishan Arora
Genevieve Gural
Rhythm Kim
Management: Team Mentors

• Dr. Kevin Shinpaugh
• Dr. Jonathan Black
• Zachary Leffke (Space@VT Ground Station manager)
• Eric Petrosky (Hume Center Graduate Student)
• Ben Hekman, Jamie Flower (Orbital ATK mentors)
• David Black, JP Burke (a.i. solutions)
## Management: Monetary Budget

### Mission Expenses

<table>
<thead>
<tr>
<th>Critical Expenses</th>
<th>Amount</th>
<th>Details</th>
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<tr>
<td>Earnest Deposit</td>
<td>$2,000.00</td>
<td>RockSat-X Flight Cost</td>
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<tr>
<td>Launch Fee Installment 1</td>
<td>$3,500.00</td>
<td>RockSat-X Flight Cost</td>
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<td>Launch Fee Installment 2</td>
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<td>Payload Component Estimate</td>
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<td>Payload Manufacturing Estimate</td>
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<td>Estimate</td>
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<table>
<thead>
<tr>
<th>Non-Critical Expenses</th>
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<th>Details</th>
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<tr>
<td>Housing Estimate (June Travel)</td>
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<td>7 nights - Chincoteague, VA</td>
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<td>Housing Estimate (August Travel)</td>
<td>$1,600.00</td>
<td>7 nights - Chincoteague, VA</td>
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<tr>
<td>Additional Team Travel Costs</td>
<td>$750.00</td>
<td>Food, gas, etc.</td>
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**Total Expenses:** $15,450.00  
**Balance:** $7,754.51

### Project Funding

<table>
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<th>Organization</th>
<th>Amount</th>
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<td>VT Foundation</td>
<td>$4,642.63</td>
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<td>AOE Department</td>
<td>$5,000.00</td>
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<td>SEC DTE Spring 2015</td>
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<td>SEC DTE Fall 2016</td>
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<td>Orbital ATK Inc.</td>
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<td>VSGC</td>
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<td>a.i. solutions</td>
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**Total Funding:** $23,204.51  
**Expected:** $16,204.51
Management: Preliminary Schedule

• NASA Design Review Process:
  – Preliminary Design Review
    • November 2, 2016
  – Critical Design Review
    • TBD December 2016

• Team Mission Schedule:
  – All design and CAD work completed
    • 1 January 2017
  – Payload subsystem testing completed
    • 1 March 2017
  – Payload integration and system testing completed (including ground station interaction)
    • 15 April 2017
  – Integration at Wallops
    • June 2017
# PMP: Latest Team Availability Matrix

## CoDR RS-X Team Availability Matrix

![Matrix Image](image)

<table>
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<tr>
<th>Oct 10-14</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<td>5:00 PM</td>
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</tr>
</tbody>
</table>

**PLEASE USE MOUNTAIN TIME ZONE TIMES**
# PMP: Latest Contact Matrix

## Virginia Tech

### Fall 2016 RS-X Contact Matrix

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Day Phone</th>
<th>Cell Phone</th>
<th>Receive Texts?</th>
<th>Email</th>
<th>Citizenship</th>
<th>Add to mailing list?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Team Lead</td>
<td>John Mulvaney</td>
<td>859-433-0409</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:Johnwm1@vt.edu">Johnwm1@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Co-Team Lead</td>
<td>Ethan Ohriner</td>
<td>703-343-5688</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:ethan095@vt.edu">ethan095@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Tony DeFilippis</td>
<td>520-820-5378</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:dtony@vt.edu">dtony@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Nick Miller</td>
<td></td>
<td></td>
<td>Yes</td>
<td><a href="mailto:nmiller1@vt.edu">nmiller1@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
<td>Marcus Wanner</td>
<td></td>
<td></td>
<td>Yes</td>
<td><a href="mailto:marcusw@vt.edu">marcusw@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
<td>Sagar Govani</td>
<td></td>
<td></td>
<td>Yes</td>
<td><a href="mailto:sagar95@vt.edu">sagar95@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
<td>Genevieve Gural</td>
<td>703-346-3609</td>
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<td>Yes</td>
<td><a href="mailto:ggural@vt.edu">ggural@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Rhythm Kim</td>
<td>757-338-4164</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:rhythm@vt.edu">rhythm@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Emma Manchester</td>
<td>410-937-9696</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:emmam95@vt.edu">emmam95@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Karl Vitale</td>
<td></td>
<td></td>
<td>Yes</td>
<td><a href="mailto:vitalekw@vt.edu">vitalekw@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Team Member</td>
<td>Austin Hannon</td>
<td></td>
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<td>Yes</td>
<td><a href="mailto:austinfh@vt.edu">austinfh@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
<td>Romy Armanous</td>
<td>804-484-0400</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:ramya7@vt.edu">ramya7@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
<td>Ishan Arora</td>
<td>703-653-4003</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:ishana97@vt.edu">ishana97@vt.edu</a></td>
<td>U.S.</td>
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</tr>
<tr>
<td>Team Member</td>
<td>Johnny Jaffee</td>
<td>203-240-7205</td>
<td>&lt;-- Same</td>
<td>Yes</td>
<td><a href="mailto:jjaffee@vt.edu">jjaffee@vt.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Team Member</td>
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</tbody>
</table>
PMP: Worries

• Dipole antenna deployment failure
  – In the beginning stages of design. Do not anticipate this being an issue at the end of design and prototyping.

• PicoZed drivers
  – Potentially will need to switch to the E310 used last year due to heritage and existing software
  – Have discussed possibility of Ettus Research donating two E310
PMP: Conclusions

• Last year’s RockSat @VT success begs for an elaboration to further push, test, and validate the capabilities of SDR. Given our success and experience with SDR, we are in a great position.

• Practical industry applications, with ADS-B being implemented on the Iridium NEXT constellation.

• Next Steps:
  – Work out PicoZed worry with Orbital-ATK
  – Improve CAD model and component layouts
  – Begin build and testing of antenna/radio components