W&J RockSat Team
Preliminary Design Review

Washington & Jefferson College
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PDR Presentation Contents

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

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

• Section 3: Subsystem Design
  – LPC Subsystem
    • LPC Block Diagram
    • LPC Trade Studies
    • Risks/Mitigation
  – ADA Subsystem
    • ADA Block Diagram
    • ADA Trade Studies
    • Risks/Mitigation
  – SLM Subsystem
    • SLM Block Diagram
    • SLM Trade Studies
    • Risks/Mitigation
PDR Presentation Contents

• Section 5: Prototyping Plan
  – LPC Prototyping
  – ADA Prototyping
  – SLM Prototyping

• Section 6: Project Management Plan
  – Org Chart
  – Schedule
  – Budget
  – Team Contact Matrix
  – Team Availability Matrix
Mission Overview

Julia Angotti
Mission Overview – Mission Statement

• Mission statement
  – We plan to measure the intensity of electron and ion currents in space. From those we will calculate the density and temperature of the plasma. We will use a plasma probe (Langmuir probe) to measure the particles.
  – We will measure sodium density in a narrow layer of the atmosphere using two cameras.
  – We plan to measure these intensities as a function of height of the Terrier-Orion rocket.
Mission Overview: Mission Objectives

• Project requirements
  – The rocket altitude must be 120 km.
  – The probe needs to be on the outside of the rocket to be in contact with the atmosphere (atmospheric port).
  – We need ~20 V at 30 mA from batteries.
  – We need an internal clock for our data.
  – We need to know the trajectory of the rocket from NASA.
  – We need access to two optical ports (1”) to take intensity measurements.
  – A Geiger counter will be used to measure high-energy electrons (to compare with the plasma data).
  – The following sensors will be useful and need to be installed: accelerometer, magnetometer.
  – The sampling rate should exceed 300 samples/second to overcome the high speed and high angular rate of the rocket.
  – The video frame rate should exceed 60 frames/second for the same reason.
Mission Overview: Theory and Concepts 1

- Plasmas are collections of electrons and positive ions. There are natural and artificial plasmas.
- Earth and other planets have plasmas at the top of their atmosphere (ionosphere). The density of the electrons is shown in the graph of the right. The RockSat trajectory goes through the E layer.
- We can collect such particles by applying a voltage to an electrode inserted into the plasma. The electrode is called a Langmuir probe.
- The sodium layer is a layer inside of Earth’s atmosphere (mesosphere) that consists of neutral sodium atoms
- These measurements are important for understanding the ionosphere.
The understanding of the ionosphere is essential to distant radio communication technology that relies on the reflection of radio wave by the ionosphere.
• Sodium layer comes from ablation of meteors.
• The light emission of sodium comes from the shift between the energy levels of electrons.
• The sodium atoms in the sodium layer are excited.
• Usually the emission is weak so we can’t see from the surface of the earth.
• A laser guide star is an application of the study of the sodium layer.
  – Shine laser of 589nm to the sky in order to excite more sodium atoms so that the sodium layers can provide a preference for reducing the effect waveform distortion due to the atmosphere.
  – This largely increases the resolution power of telescopes on the earth.
Even the laser guide star is usually created during night and our experiment would be during daytime, since the position of the sodium layer would not change dramatically, our measurement would be meaningful.

The reason of the position shift is because of the intensity of light from the sun.
Concept of Operations

- Power should go on at launch \((T = 0)\) tripped by the G switch, then turn off at landing. All instruments and microcontrollers should stay on after launch.

- The plasma probe voltage would turn on at \(T = +70\) s and turn off at \(T = +240\) s. The main part of data collection would be between those times.

- We plan to take video throughout the flight. The sodium measurements will be taken from 60 to 90 seconds and from 4:00 to 4:20 minutes.

- Sampling rates and frame rates should be constant throughout the flight.

- Power should be turned off at the end of the flight.
ConOps Schematic

Altitude

Sodium layer
- $t \approx 1.3-1.5$ min
- Altitude: 80-95 km

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

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

High Tumble Rate
- $t \approx 4.0$ min
- Altitude: 95 km

Plasma region
- $t \approx 1.5-3.5$ min
- Altitude: 90-120 km

Low spin
- $t \approx 5.5$ min
- Chute Deploys

$\mathbf{t = 0 \text{ min}}$
- G switch triggered
- All systems on
- Begin data collection

$\mathbf{t = 15 \text{ min}}$
- Splash Down
Mission Overview: Expected Results

- The density of electrons is shown as a function of height. Peak density is $5 \times 10^{11}$ electrons/m$^3$.
- The density shown is for the daytime. Plasma needs sunlight so the density at night is much lower (graphic).
- Sodium layer: the peak intensity should at least triple from the background near 80 km. It is most intense around 80-95 km.
- Wavelength around 589 nm should be observed in the sodium layer.
- Energetic electrons should show a peak around 20-25 km then decrease with height.
- The magnetic field decreases with height as a power-law fit.
Success Criteria

• Minimum Success Criteria:
  – Plasma: Voltage sweep through the flight.
  – Camera: Minimum amount of data: Video from one of the two cameras

• Comprehensive Success Criteria:
  – Plasma: full coverage above 90 km
  – Camera: continuous video until splashdown
  – Electron measurements from the Geiger counter
Functional Requirements:

- System shall have measured I/V data recorded in the Arduino throughout the flight as a function of time.
- From this we shall measure the electron density of the plasma.
- The plasma experiment shall measure the electron temperature and floating potential from the I-V curve.
- This experiment shall attempt to measure the plasma potential.
- The Arduino Timer code works and provides time accurate to 1 microseconds based on the speed we varied the voltage of 1 V/s error we have in the ADC.
## Functional Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>• System shall have measured I/V data recorded in the Ardiuno throughout the flight as a function of time.</td>
<td>Test</td>
<td>System will be tested on the ground with a plasma to make sure we get good I/V data.</td>
</tr>
<tr>
<td>• The Ardiuno Timer code works and provides time accurate to 1 microseconds based on the speed we varied the voltage of 1 V/s error we have in the ADC.</td>
<td>Inspection</td>
<td>The Ardiuno System's timing will inspected during the testing of the Langmuir probe to insure that the times correspond to the right voltage.</td>
</tr>
<tr>
<td>The full system shall fit two RockSat-X canisters.</td>
<td>Inspection</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>Test</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>Inspection</td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
De-Scopes & Off-Ramps

• If the op amps cannot be combined into a small number, we will use a greater number of components even if that means spreading them out over multiple PCBs.
System Overview

Jiaoyi Yang
Pat Fullerton
System Definitions

• The following are the main subsystems of the payload:
  • LPC: Langmuir Probe Circuit
  • ADA: Arduino Data Acquisition
  • SLM: Sodium Layer Measurement
System-Level Functional Block Diagram (from CoDR)

- **Makrolon plate (top)**
  - Arduino and plasma electronics - storing data (mounted to plate)
  - Small sensors
  - Power

- **Makrolon plate (bottom)**
  - Cameras
  - Raspberry Pi and electronics – controlling cams (mounted to plate)

- Connected to each other with standoffs

- Mounts to top of canister

- Placed above center of canister for viewing (attached to top plate)
3D Design in Preparation

- We are still working on a 3D mechanical design using TinkerCad.
- Several of the components are complete, but they have not been assembled yet.
- The final result should be like the following graphic.
Design Overview: Ports

- The plasma experiment needs a special port. We are planning to use the dual SMA connector.
- We will need to modify the pocket cover (but not the pocket) by adding an external electrode. This will be the plasma probe.
- Interface between port and payload.
  - Electrical: 3 wires of variable length (0.25-1 m) as needed.
  - Mechanical: at this point we do not need a mechanical connection (if this changes, 3D printing is an option).

• Requirements in the User’s Guide:
  – Predicted mass: 3 kg based on payload only. We will need to add 1.5 kg of ballast.
  – Predicted volume: The payload will fit in half a canister.
  – Activation: we are planning to use a G switch activation.
  – Special requests: external port and optical port.
Design Overview: Shared Can Logistics

- We are requesting $\frac{1}{2}$ a canister. We will learn of the canister partner at this telecon (PDR).

- Plan for collaboration: We will contact the canister partner via email and possibly telecon.

- Mounting to the top or bottom of canister: it should not make a difference. We plan to use a mid-mounting plate for the camera facing the optical port.
LPC Design
LPC: Langmuir Probe Circuit

Garrett French
LPC Design

• The Arduino will be coded to output a triangle wave from -5V to 5V. The differential amplifier will then measure the difference between V-probe and the input voltage.
LPC: Trade Studies

Trade study for a differential amplifier used in the Langmuir probe circuit.

<table>
<thead>
<tr>
<th>Differential Amp</th>
<th>AD8231</th>
<th>AD8230</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>&gt;5</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Variable Gain</td>
<td>1,2,4,8,16,3,2,64,128 V</td>
<td>10-1000 V</td>
</tr>
<tr>
<td>Drift</td>
<td>50 nV/c</td>
<td>50 nV/c</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>2 V/μs</td>
<td>1.1 V/μs</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>9</strong></td>
<td><strong>8.4</strong></td>
</tr>
</tbody>
</table>
LPC: Experiment

- We have been testing several components such as vacuum tubes (LPC subsystem; one of the tests is shown below) and op amps (ADA subsystem).
ADA Design
ADA: Arduino Data Acquisition

Patrick Fullerton
ADA: Trade Studies

- The following table shows a trade study for the ADA subsystem.

<table>
<thead>
<tr>
<th></th>
<th>Arduino</th>
<th>Raspberry Pi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$29.95</td>
<td>$35.00</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Clock Speed</strong></td>
<td>16MHz</td>
<td>700MHz</td>
</tr>
<tr>
<td><strong>A/D Converters</strong></td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Programming Language</strong></td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>
SLM Design

SLM: Sodium Layer Measurement

Jiaoyi Yang

Akira Yamashita
Subsystem Design Section

- **Single-board computers**
  - Run code
  - Save the video from camera
  - Require
    - Large memory

- **Camera**
  - Take video
  - Require
    - High frame rate
    - Resolution
    - Small size
SLM: Block Diagram

Legend

Data/Control
Power

Power

Camera

Raspberry Pi
## SLM: Trade Studies – Single Board Computer

<table>
<thead>
<tr>
<th></th>
<th>Raspberry Pi</th>
<th>Nano Pi</th>
<th>ODROID-XU4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Memory</strong></td>
<td>1G RAM</td>
<td>1G RAM</td>
<td>2G RAM</td>
</tr>
<tr>
<td><strong>CPU</strong></td>
<td>1.2 GHz</td>
<td>1.4 GHz</td>
<td>2 GHz</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>29 $</td>
<td>33$</td>
<td>59$</td>
</tr>
</tbody>
</table>
## SLM: Trade Studies - Camera

<table>
<thead>
<tr>
<th></th>
<th>Arducam OV5647</th>
<th>Arducam Sony IMX219</th>
<th>Raspberry Pi Module Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frame Rate</strong></td>
<td>30 fps</td>
<td>60 fps</td>
<td>30 fps</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>1080P</td>
<td>1280 x 720P</td>
<td>1080P</td>
</tr>
<tr>
<td><strong>Sensor</strong></td>
<td>5M Pixel</td>
<td>8M Pixel</td>
<td>5M Pixel</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>25 x 24.5 mm</td>
<td>36 x 36 mm</td>
<td>25 x 24 mm</td>
</tr>
<tr>
<td><strong>Wide Angle</strong></td>
<td>54°</td>
<td>91°</td>
<td>75.7°</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>14.99$</td>
<td>64.99$</td>
<td>21.99$</td>
</tr>
</tbody>
</table>
SLM: Risks

SLM.Risk 1: Raspberry Pi doesn’t work
• have 2 G switch in parallel
SLM.Risk 2: Run out of power
• test the power source before the launch
• save the video piece by piece
SLM.Risk 3: Dust on camera
SLM.Risk 4: Camera shift caused by vibrate
SLM.Risk 5: Filter break and lose comparison
SLM.Risk 6: Not enough memory for video
SLM.Risk 7: Rocket doesn’t launch
SLM: Risk Matrix

1: Raspberry Pi doesn’t work: no video
2: Batteries run out of power: video ends
3: Dust/debris on camera: blurry image
4: Camera shift caused by vibration: limited field of view
5: Filter breaks: we lose comparison
6: Not enough memory for video
7: Rocket doesn’t launch
Test/Prototyping Plan

Patrick Fullerton
**Prototyping Plan**

**Risk/Concern**
- Concern about the performance of the plasma probe in the E layer.
- Concern about not being able to get enough angle of field due to the position of where the cameras are mounted and the length of the cable connecting the camera and raspberry pi. *(Risk: Could not have enough samples of data)*

**Action**
- Prototype the probe so that it is available under high speed and voltage.
- Prototype a socket so that we can fix the position of cameras to make it stable and a cable long enough for any mounting position arrangement.
Project Management

*Julia Angotti*
Schedule highlights

- Fall 2017: Design phase
  - Weekly team meetings; working meetings
- Monthly reviews (CoDR, PDR, CDR)
- January 2017: Downselection
- Spring 2018: Development and testing
  - Team and working meetings
- Reviews and regular telecons
- June 21, 2018: Launch
Team Contact Matrix

- Contact matrix shown below:

<table>
<thead>
<tr>
<th>RSC 2018 Contact List for: Washington and Jefferson College</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Member</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Julia Angotti</td>
</tr>
<tr>
<td>Patrick Fullerton</td>
</tr>
<tr>
<td>Garrett French</td>
</tr>
<tr>
<td>Akira Yamashita</td>
</tr>
<tr>
<td>Jiaoyo Yang</td>
</tr>
<tr>
<td>Dimitris Vassiliadis</td>
</tr>
</tbody>
</table>

- We will exchange documents via GoogleDrive (but can use DropBox if RockSat requests it).
Team Availability Matrix

• Team meeting: Mondays, 6:00-7:00 p.m. EST

• Telecon time: Thursdays, 1:00-2:00 p.m.
Budget

• Our two sponsoring organizations have approved the project (end of August and September 15).
• We have purchased several components for LPC, ADA, and SLM.
• We are still working on the full budget.
Worries

• Programming the plasma experiment on Arduino.
• Testing the G switches for activation sequence.
Conclusion

• Our mission is to measure electric currents and sodium density in the top part of the atmosphere.
• We have continued testing the plasma electronics. We have worked on TinkerCad, but do not have a full assembly yet.
• We have also continued testing the camera using Python code. We will make additional changes to the code.