CDR Presentation Outline

• Section 1: Mission Overview
• Section 2: System Overview
• Section 3: Subsystem Design
• Section 4: Prototyping/Analysis/Results/Plans
• Section 5: Manufacturing Plan
• Section 6: Testing Plan
• Section 7: User Guide Compliance
• Section 8: Project Management Plan (PMP)
• Section 9: Appendix (not presented)
1.0 Mission Overview

Name of Presenter
Mission Overview: Action Items from PDR

• Added detail to power budget, weight budgets, and User’s Guide compliance
• Established power subsystem lead
• Created more detailed structural drawings
Mission Overview: Mission Statement

• The Polar Atmospheric Winter Student Sounding rocket (PAWSS) mission will provide *in situ* atmospheric measurements to be integrated with ground-based measurements to support the investigation of polar mesospheric and lower ionospheric phenomena.
Mission Overview: Primary Mission Objectives

• Provide in situ measurements of the mesosphere and lower ionosphere.
• Integrate ground based and \textit{in situ} data to improve scientific understanding of the mesosphere and lower ionosphere.
• Develop students as scientists and engineers prepared to work in a global environment.
• Modernize and test scientific instrumentation for atmospheric measurements to be used on future missions.
## Mission Overview: Concept of Operations

### Polar Atmospheric Winter Student Sounding (PAWSS) Rocket

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Phase</th>
<th>Timed Events</th>
<th>Description</th>
</tr>
</thead>
</table>
| t-10+    | Ground station initialization | • Activate ground station  
• Report status of ground station activation  
• If successful, begin radio transmission toward rocket TEC  
• Report status of radio transmission | |
| t(10<->3) | Payload initialization | • Ground Support Equipment (GSE) activated power lines become active at PAWSS-specified time  
• Power on flight computer  
• Pause a discrete amount of time in order for power fluctuations stop  
• Primary electronics power on  
• Telemetry is established, system data begins to transmit  
• Initialize basic systems (power, Guidance Navigation and Control (GNC), data handling)  
• Establish available power  
• Establish current and expected power consumption  
• Establish spatial orientation  
• Boot individual sensor systems to sleep mode (Langmuir, TEC, Lidar)  
• Transmit initialization data | |
| t:0      | Launch | | |
| t:0.6    | End of Molotov Burn | | |
| t:x      | Nose Cone Separation, De-spin | | |
| t-x (50km) | Activation of Langmuir Probe | Timed Event 1 | • Timed event wakes Langmuir probe  
• Deploy Langmuir probe boom  
• Check status of boom deployment  
• If boom deployed successfully, activate Langmuir probe, begin collecting data  
• If boom not deployed successfully, activate Langmuir probe, test data validity  
• If data is valid, begin collecting data  
• If data is invalid, explore failure options  
• Data is transmitted at specified rate along communication lines to data handler and telemetry  
• Data collection and transmission continues | |
| t-x (50km) | Activation of TEC sensor | Timed Event 2 | • Timed event wakes Total Electron Content (TEC) sensor  
• Deploy TEC sensor antenna  
• Check status of TEC antenna deployment  
• Activate TEC sensor antenna  
• Search for ground station transmission  
• Report status of transmission receipt  
• If successful, data collection begins  
• If unsuccessful, explore failure options  
• Data is transmitted at specified rate along communication lines to data handler and telemetry  
• Data collection and transmission continues | |
| t-x (50km) | Activation of Lidar | Timed Event 3 | • Timed event wakes Lidar  
• Report status of Lidar activation  
• If successful, begin data collection  
• Test data validity  
• If data is valid, continue data collection  
• If data is invalid, explore failure options  
• If unsuccessful, explore failure options  
• Data is transmitted at specified rate along communication lines to data handler and telemetry  
• Data collection and transmission continues | |
| t-3      | Apogee | | |
| t-15     | Splashdown | • End data collection from all systems  
• Clear data buffer | |
Mission Overview: Concept of Operations

- This Matrix cannot be finalized until details of the rocket are known.

<table>
<thead>
<tr>
<th>Event</th>
<th>Time On</th>
<th>Dwell</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE 1</td>
<td>T-300 sec</td>
<td>660 sec</td>
<td>Supply power to the power subsystem for distribution.</td>
</tr>
<tr>
<td>GSE 2</td>
<td>T-300 sec</td>
<td>660 sec</td>
<td>Redundant. See above.</td>
</tr>
<tr>
<td>TE-1</td>
<td>T+60 sec</td>
<td>5 sec</td>
<td>Activate Langmuir Probe boom deployment burn wires 1 and 2 (stage 1: probe flop).</td>
</tr>
<tr>
<td>TE-2</td>
<td>T+60 sec</td>
<td>5 sec</td>
<td>Activate TEC System antenna deployment burn wire</td>
</tr>
<tr>
<td>TE-3</td>
<td>T+60 sec</td>
<td>5 sec</td>
<td>Activate Langmuir Probe boom deployment burn wires 1 and 2 (stage 2: boom extension).</td>
</tr>
<tr>
<td>TE-R</td>
<td>T+65 sec</td>
<td>265 sec</td>
<td>Activate Lidar System laser diodes</td>
</tr>
</tbody>
</table>
Mission Overview: Success Criteria

Minimum Success Criteria:
– Collect valid data from at least one instrument system.
  – Will prove lidar as viable rocket-borne instrument
  – Confirm SDR TEC is comparable to analog version
  – Langmuir probe data can be correlated with 4D data
  – Data may have scientific utility besides PMWEs

Comprehensive Success Criteria:
– Collect data that furthers understanding of PMWEs.
2.0 System Overview

Name of Presenter
Systems Overview: System Changes Since PDR

- Please update me on your actions assigned during PDR (list them)
  - See first slide

- What major changes have you made since PDR?
  - Most data will be sent on the digital line (higher rate)
  - Deployment mechanism defined
  - Power subsystem handling regulation
Science Mission Statement

The mission goal is to study the Polar Mesosphere Winter Echoes and their correlation with electron density and neutral turbulence and provide atmospheric data in the lower mesosphere.
Measurements and Expected Results

- Electron density – TEC and Langmuir
- Neutral turbulence – Lidar
PMWE reflectivity
Importance

– Neutral turbulence and electron density during PMWEs
– Our measurements will prove or disprove the causation of PMWEs by neutral turbulence and electron density
System Overview: Design

Software, Electrical, and Mechanical designs will be covered by the applicable subsystems in their portions of this presentation.
System Overview: Description of Partnerships

• University of Oslo
  • Constructing 4D “hockey puck” system.
  • PAWSS will assist with antenna analysis
• Dr. Martin Friedrich – University of Graz
  – Original developer of TEC System
  – Wants analog technology to be updated
• Stephen Lovas - PSU Ph.D Candidate
  – Working on SDR version of TEC for thesis
  – G-Chaser team responsible for ground station, power supply, data handling
  – Organizing 4D antenna analysis
• Doug Rowland – NASA
  – Team visited NASA in early November
  – Dr. Rowland to visit PSU in February
• G-Chaser science summit early next year
De-Scopes and Off-Ramps

• Flight spares will be developed time and budget permitting
System Overview: Special Requests

- Launch when PMWEs are expected based on ground-based radar observations
  - PAWSS science team will develop a good understanding of what happens during a PMWE, to inform launch time request
- Shed skin as close to 50km as possible in order to deploy probes in time to collect data in PMWE region (65-90km)
- Increased boom deployment speed (discussed later)
- Formation of a partnership with Alomar Observatory for ground-based science
- Test flight spares at WFF in June
- Set up ground station for TEC at Andoya
Science-Specific Requests

- Payload must be able to see the sun at 50 Km therefore we must launch during the day for us to be able to get attitude data.
- We must have ground radar and Lidar operating before and during flight to be able to observe atmospheric conditions and determine launch window.
- Shed skin and nose cone at 55 km or lower.
3.0 Subsystem Design

Name of Presenter
### Subsystem Design: Detailed Weight Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Item</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REQUIRED</td>
<td>Deck and Connector</td>
<td>1.54</td>
</tr>
<tr>
<td>PWR</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>LIDAR</td>
<td></td>
<td>3.198</td>
</tr>
<tr>
<td>TEC</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>LANG PRB</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>STR</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>CDH</td>
<td></td>
<td>0.03968</td>
</tr>
<tr>
<td>AD</td>
<td></td>
<td>0.0275</td>
</tr>
<tr>
<td>Leftover</td>
<td></td>
<td>4.15482</td>
</tr>
<tr>
<td>Totals:</td>
<td></td>
<td>9.45518</td>
</tr>
</tbody>
</table>
# Subsystem Design: Detailed Power Budget

## Penn State University - Power Budget

**Date 12/1/17**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Subsystem Current (A)</th>
<th>Max Battery Current (A)</th>
<th>Start Time (min)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIDAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser diodes</td>
<td>5.0</td>
<td>6.60</td>
<td>1.18</td>
<td>1.08</td>
<td>4.42</td>
<td>33.00</td>
<td>0.087</td>
</tr>
<tr>
<td>Detector bias</td>
<td>5.0</td>
<td>0.25</td>
<td>0.04</td>
<td>0</td>
<td>5.5</td>
<td>1.25</td>
<td>0.004</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>5</td>
<td>0.5</td>
<td>0.09</td>
<td>0</td>
<td>5.5</td>
<td>2.50</td>
<td>0.008</td>
</tr>
<tr>
<td>CDH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Computer</td>
<td>5</td>
<td>0.5</td>
<td>0.09</td>
<td>0</td>
<td>5.5</td>
<td>2.50</td>
<td>0.008</td>
</tr>
<tr>
<td>RS-232</td>
<td>9</td>
<td>0.034</td>
<td>0.01</td>
<td>1</td>
<td>4.5</td>
<td>0.80</td>
<td>0.002</td>
</tr>
<tr>
<td>Analog TEC</td>
<td>20</td>
<td>0.04</td>
<td>0.03</td>
<td>1</td>
<td>4.5</td>
<td>0.80</td>
<td>0.002</td>
</tr>
<tr>
<td>SDR TEC</td>
<td>5</td>
<td>0.03</td>
<td>0.01</td>
<td>1</td>
<td>4.5</td>
<td>0.80</td>
<td>0.002</td>
</tr>
<tr>
<td>Langmuir</td>
<td>6</td>
<td>0.23</td>
<td>0.05</td>
<td>1</td>
<td>4.5</td>
<td>1.38</td>
<td>0.004</td>
</tr>
<tr>
<td>Power</td>
<td>28.0</td>
<td>0.02</td>
<td>0.02</td>
<td>0</td>
<td>5.5</td>
<td>0.42</td>
<td>0.004</td>
</tr>
<tr>
<td>ADS</td>
<td>28.0</td>
<td>0.50</td>
<td>0.50</td>
<td>0</td>
<td>5.5</td>
<td>14.00</td>
<td>0.046</td>
</tr>
<tr>
<td>Burn Wires (3)</td>
<td>28.0</td>
<td>3.00</td>
<td></td>
<td>1</td>
<td>0.08</td>
<td>84.00</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>140.31</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Total Power Capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Over/Under</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GSE Current Max (A):</th>
<th>0.832357143</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE Current Max (Burn Wires and Lidar Diodes) (A):</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># of Flights Margin</th>
<th>6.0</th>
</tr>
</thead>
</table>
Subsystem Design:

- List all the subsystems in your payload that will be covered in this section
  - Power
  - CDH
  - Langmuir
  - TEC
  - Lidar
  - AD
  - Structures
  - 4D
2.0 Power System Overview

Steven Krupa
Power System Changes Since PDR

- Communicate directly through analog data channel instead of through CDH.
- Will now handle power regulation in addition to distribution
  - Centralized regulation reduces unnecessary duplication of voltage regulators.
- Power filtering will be simple and only provide over-voltage and over-current protection
System Overview: Functional Block Diagram

From the users guide:

+28V Battery Bus

Polyswitch 1.85A

Polyswitch 3.75A

GSE Controlled Power

GSE-1

GSE Controlled Power

GSE-2

[(GSE-1) + (GSE-2)] < 1.85 A

Timer Controlled Event RA

TE-RA

Timer Controlled Event RB

TE-RB

Timer Controlled Event 1

TE-1

Timer Controlled Event 2

TE-2

Timer Controlled Event 3

TE-3
System Overview: Block Diagram (Power)

- **GSE-1**
- **GSE-2**
- **TE-1**
- **TE-2**
- **TE-3**
- **TE-RA**
- **TE-RB**
- **Over-Voltage Protection**
- **Current Monitoring***
- **LIDAR Voltage Regulation**
- **GSE Voltage Regulation**
- **PTC Fuse**

**Communications details on next slide**
System Overview: Block Diagram (Communication)

- Current/Voltage monitor
- Current/Voltage monitor
- Current/Voltage monitor
- Microcontroller
- A/D Line
- CDH ADC
- Analog
- I2C
System Overview: Mechanical Design

- Utilize a single board with locking connectors for each subsystem
  - Locking connectors will be used to ease per-instrument testing before flight.
    - After testing, connectors will be permanently joined with adhesive.
  - PCB will be 2mm thick to increase strength
  - Screw-mounts for the PCB will be within 4cm of power connectors to reduce mechanical strain/flex of PCB
  - All wired connections will use stranded wire
    - Power connections will use 16AWG wire
  - Cable runs will be tied to the structure in accordance to the user manual
  - Connectors will be arranged for shortest cable runs and minimum wire cross-over.
System Overview: Electrical Design

• Three functions
  • Electrical protection
    • Uses resettable fuses and veristors for over-voltage and over-current protection
  • Power monitoring
    • Current through each line will be monitored and encoded onto analog signal with a microcontroller.
    • Battery voltage will be measured as well
  • Voltage regulation
    • Centralized regulators for each of the voltages required for all other systems
Electrical design: Fault Protection

• Metal-Oxide-Veristors (MOV’s) will be used to shunt short voltage transients of over 50V.
  – Placed between power lines (GSE and timed) and ground
  – Only conducts after voltage threshold is met
  – Prevent damage from erroneous high voltages

• Positive temperature coefficient thermistors (PTC) will be used as resettable fuses for each power system.
  – Will isolate over-current faults to each system.
    • Prevents a single failure from removing power to entire voltage rail
  – Slow-acting nature of PTC’s allows inrush currents to pass
Electrical design: Power monitoring

- Power monitoring of each power line to each subsystem will use a power monitoring IC.
  - Utilizes a low-value shunt resistor (less than 0.1ohms) to measure currents to each system
  - Measures a voltage as well, but only one voltage measurement will be taken (battery voltage)
  - Communicates all data over I2C bus
  - Originally was going to use LTC4151, but the voltage input range was incompatible with current measurements less than 7V

- Micro-controller (Model # TBD) will read data from each IC and encode information on an analog signal for direct transmission to a single A/D line.
  - CDH will read this analog value as well in order to know the state of each system.
  - Analog output will be from the micro-controller’s onboard ADC
  - Will likely use the same type of micro-controller that’s on TEC
Electrical Design: Regulation

• Voltage regulation will be done via pre-made step down modules
  – Provide optimum performance, reliability, and ease of design

• Specific brands and model numbers are yet to be determined, but Vicor will likely be a major source
Schematics will be completed once microcontroller and current sense modules are selected. Most design can be achieved directly from the block diagram.
System Overview: Software Design

• Software implemented on microcontroller will read each current lane simultaneously.

• Output will occur 10-times per second over analog line
  • The signal will start with a synchronization pulse that will be a higher voltage than any other signal, and it will then step through each current value. (Diagram pending)
Further system development

• This design, as it stands, it not final
  – Current monitoring IC must be chosen, will likely be a sense amplifier with a multi-channel ADC. Needs to work down to 5V supply.
  – Voltage regulators must be selected with specifications that match the power requirements set forth by each subsystem.
  – The location of over-current protection may change as more optimal locations are found.
  – Power requirements and hazards of burn wires will need to be determined in order to verify the need for current monitoring and protection.
  – Power filtration may be added if testing proves that the power lines and systems connected to them are susceptible to noise.
System prototyping and testing

• Most components are SMT, so they will be mounted to adapter boards for use in a breadboard.

• Performance of PTC’s will be analyzed
  – Trip and hold current at different ambient temperatures and pressures will be recorded.
  – Differences in performance caused by conformal coating will be determined

• Simulated fault conditions will test the stability of the entire system

• Noise output from regulators will be tested to make sure it doesn’t cause issues with systems

• Environmental noise tests will be performed to determine the need for additional power filtration outside of each system
Risks

• PTC heating up and going open-circuit
  – Unlikely, catastrophic depending on affected system. CDH is the most important system to keep powered up
  – Prevent by placing power distribution far from heat sources any by fully testing PTC fuses to ensure no false trips.

• PTC not recovering after over-current event
  – Mildly possible, mildly catastrophic depending on affected system. Because the rocket is already fused with PTC’s, this issue is likely unavoidable in certain instances
  – Prevent by testing hold current of PTC’s and making sure that systems won’t trip the system during a sudden re-boot.

• Failure of MOV
  – Mildly Unlikely, not catastrophic. If the MOV fails, then the high voltage transient (and future transients) goes through GSE and TE lines. Voltage regulators are likely able to handle this, but other systems may suffer
Testing Plan: Power

• Power Regulation:
  • All regulation circuitry will be simulated using EDA software, prototyped on a breadboard, and then tested on a PCB. This will minimize the possibility of circuits behaving unexpectedly, or outright failing.
  • A benchtop power supply or a LiPO battery will be used as a stand-in for the battery provided by CoSGC. This will allow us to characterize how the system will behave as the battery nears its lowest voltage.

• Power Measurement:
  • All regulation circuitry will be simulated using EDA software, prototyped on a breadboard, and then tested on a PCB. This will minimize the possibility of circuits behaving unexpectedly, or giving false readings.
  • All Circuits and components will be tested in a thermal chamber to verify that components function properly over the expected range of temperatures.
CDH
Functional Block Diagram
## CDH Pinout

<table>
<thead>
<tr>
<th>PIN NUMBER</th>
<th>FUNCTION</th>
<th>ASSIGNMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>P9 24</td>
<td>UART1_TX</td>
<td>Asynchronous Line</td>
</tr>
<tr>
<td>P9 22</td>
<td>UART2_RX</td>
<td>Lidar</td>
</tr>
<tr>
<td>P9 11</td>
<td>UART4_RX</td>
<td>Langmuir Probe</td>
</tr>
<tr>
<td>P8 38</td>
<td>UART5_RX</td>
<td>TEC SDR</td>
</tr>
<tr>
<td>P9 19, 20</td>
<td>I2C</td>
<td>Attitude Determination</td>
</tr>
<tr>
<td>P9 23</td>
<td>GPIO_49</td>
<td>Signal to Lidar</td>
</tr>
<tr>
<td>P9 33, 35-40</td>
<td>Analog IN</td>
<td>Power</td>
</tr>
</tbody>
</table>

In addition to these pins, 16 GPIO pins will be used to communicate data to the parallel line. These pins have not been determined yet. Additionally, the specific number of analog inputs coming from power has not been determined yet.
Power and Data

• Power requirements for CDH Flight Computer are as follows:

  Operating Voltage: 5V

<table>
<thead>
<tr>
<th>State</th>
<th>Approximate Current Draw (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>320</td>
</tr>
<tr>
<td>Moderate Work Load</td>
<td>400</td>
</tr>
<tr>
<td>Heavy GPIO Work Load</td>
<td>440</td>
</tr>
<tr>
<td>Kernel Boot Peak</td>
<td>460</td>
</tr>
<tr>
<td>Deep Sleep</td>
<td>51</td>
</tr>
</tbody>
</table>

• CDH will not have any data to transmit from itself except potential system error statuses over the parallel line.
Mechanical and Electrical Interfaces

• Mechanical
  – Mounting for the flight computer using screws, bolts, etc.
  – Mounting for the RS-232 circuit

• Electrical
  – 5V barrel plug for the flight computer coming from Power
  – Power for the RS-232 circuit coming from power
Hardware Used

- **Flight Computer:**
  - BeagleBone Black, Indust
  - Weight: 39.68g

- **RS-232 Circuit:**
  - Texas Instruments SN75188
  - Weight: <1g
CDH Software Design

- CDH software will be written in C++, using C++ 11 standards. The software shall use some object oriented design, as well as multiple threads to facilitate in concurrent data collection and transmission, as well as to maximize efficiency.
- The high level design of CDH software is as follows:
CDH Software Design, cont.

• A data collection module shall control the collection of data synchronous to the data collection rates of the science instruments.
  – This module shall probably contain a thread(s), polling the sensors using the science sensor interfaces at the frequency at which the instruments will be sending data to the flight computer.

• Science subsystem interfaces shall be the interface between the data collection module and the communication protocols used to communicate to the instruments.
  – This will involve a class for each instrument, having functionality to properly read data from each instrument and present the data in a proper form for the data collection module

• Thread-safe data buffers shall be used to store the data temporarily, as for a portion of the flight we are expecting to collect data faster than we can transmit
  – These data buffers will most likely be a lightweight implementation of a stack, using mutexes to guard data during access.

• The telemetry interface shall serve as the interface between the data collection module and the communication protocols of the telemetry interface
  – This shall involve a class with functionality to present the data to the telemetry interface as per the Telemetry ICD.

• The power interface shall serve to be the interface between the data collection module and the communication protocol used to communicate with the power subsystem.
  – This will involve a class having functionality to properly read power data.

• Additionally, a minimal process monitor will be integrated to potentially re-start CDH’s software if it crashes at any point
CDH Software Design, cont.

- The CDH software flow diagram is as follows:

```
Payload Powered On → Initialize basic systems, begin transmitting system state data → Launch → Wait for science subsystems to be woken up by timed events → Check status of subsystems

System power cut off

Yes → Finish collecting data, send as much data to telemetry interface as possible before power down

Time to stop collecting data?

Yes → Corrective action taken by subsystem activated improperly

No → Instruments activated properly?

Yes → Collect data from subsystems & Format and send data to telemetry interface concurrently

No → Collect data from subsystems & Format and send data to telemetry interface concurrently
```
CDH Risk Matrix

- Flight computer does not boot properly
- CDH software crashes and cannot be re-started by the process monitor
- RS-232 Circuit fails
- CDH software crashes due to un-tested condition
CDH Prototyping

- CDH communication protocols, namely UART, I2C, and general GPIO, will be prototyped and tested first to ensure that CDH can properly and efficiently communicate with everything on board it needs to communicate with.
  - There is a large amount of legacy code from OSIRIS-3U which can be re-used for the communication protocols
- CDH communication to the telemetry interface using a 37-pin D-sub connector to simulate the Telemetry interface shall be prototyped as well.
- The CDH process monitor shall be prototyped and tested as well, to ensure that it can properly re-start CDH mission software upon any software related crash.
- Finally, CDH mission software shall be developed and unit-level tested, to ensure that CDH can properly step through its concept of operations in its entirety.
- All the prototyping shall be done using a BeagleBone Black as the flight computer, microcontrollers simulating the subsystems, and a 37-pin D-sub connector to simulate the telemetry interface.
- The analysis of this prototyping shall include analyzing CDH's performance in terms of speed of data transfer, data throughput to the telemetry interface, and power consumption.
Testing Plan: CDH Hardware

• Command and Data Handling Board:
  • The design shall be simulated in EDA software to ensure that all support circuitry functions as intended. Using ADS the board will be analyzed for crosstalk between signal lines.
  • The support circuitry will be constructed on a breadboard to verify that when the development board is constructed that microcontroller is powered on using the correct start sequence and that all power circuitry operates at the intended operating point.
  • A development board for CDH will be fabricated to test the operation of the microcontroller circuit. This will then be thermal cycled, so that the effects of thermal variation are fully characterized.
Testing Plan: CDH Software

- Command and Data Handling Software:
  - Software will be written and tested on desktop computers to verify that all protocols and that the concept of operations are coded correctly. The system should be able to step through the entire ConOps without the physical hardware.
  - Once validated on lab computers, the flight software will be loaded on to the development board mentioned in the previous section. This will allow for benchmarking of the software, and verification that it will function as expected in flight. This will be conducted without the scientific instruments to minimize any damage that the flight computer could cause to them.
  - Once the software has been tested on the development board, it will be loaded onto the engineering model of the payload. This will be one of the final steps in testing the payload. This will verify that the payload is ready for delivery and flight.
Langmuir Probe
Langmuir Probe: System Overview

- The PAWSS payload will fly two Langmuir probes: One SSPL Pulsed Langmuir Probe (PLP) and one Fixed-biased Langmuir Probe (FLP).
  - The Pulsed Langmuir Probe will avoid charge build up and distortion of data, can be set in various modes: swept & pulsed
  - The Fixed Langmuir Probe will provide a high spacial resolution of our data
  - Both Langmuir Probes will have a coating to mitigate charge build up, while not impeding data gathering

- Both Langmuir Probes will follow Orbital Motion Limited Theory as well as the rocket: probe surface area ratio requirements
  - The probe radius will be less than the Debye Length and the length to radius ratio will be much greater than 1
  - The rocket to probe area will be determined based on conductive rocket surface area, conductive rocket surface area material, and atmospheric plasma qualities
Langmuir Probe: System Changes

- Both Langmuir Probes will be made of stainless steel and gold plated.
- There will be two booms, one for each probe.
- The booms will be made out of tape measure.
- The circuit that was flown on Osiris 3U is being remolded to fit in the payload, but functionality will remain the same.
# Langmuir Probe: Power and Data

<table>
<thead>
<tr>
<th></th>
<th>*Voltage (V)</th>
<th>*Power Requirement (W)</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLP</td>
<td>6-28</td>
<td>2.3</td>
<td>Current of plasma relative to our voltage</td>
</tr>
<tr>
<td>FLP</td>
<td>6-28</td>
<td>2.3</td>
<td>Current of plasma relative to our voltage</td>
</tr>
</tbody>
</table>
### Langmuir Probe: Mass Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLP</td>
<td>35</td>
</tr>
<tr>
<td>FLP</td>
<td>35</td>
</tr>
<tr>
<td>Boom &amp; Wiring</td>
<td>10</td>
</tr>
<tr>
<td>Shielding</td>
<td>35</td>
</tr>
</tbody>
</table>
## Langmuir Risk Matrix

<table>
<thead>
<tr>
<th></th>
<th>Negligible</th>
<th>Marginal</th>
<th>Critical</th>
<th>Catastrophic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable</td>
<td>Boom does not deploy</td>
<td></td>
<td>Interference from other payloads causes distorted data</td>
<td></td>
</tr>
<tr>
<td>Possible</td>
<td></td>
<td></td>
<td>Boom deployment impacts other instruments</td>
<td></td>
</tr>
<tr>
<td>Improbable</td>
<td></td>
<td>Communicaton to CDH is lost</td>
<td>FPGA explodes</td>
<td></td>
</tr>
</tbody>
</table>
Langmuir Probe: Required Hardware & Restrictions

- **Circuits**
  - One will be operating in pulsed Langmuir probe mode
  - One will be operating in fixed Langmuir probe mode
  - Will be mounted in housing within payload bay

- **Langmuir probes**
  - One will have a sweeping biased
  - One will be at a fixed biased

- **Boom**
  - There will be one boom for each probe
  - Triaxial cables shall connect the probe to it’s circuit
What needs to be finalized & Concerns

- Boom deployment system is still being design

- The conductive surface area of the rocket while we are acquiring data is unknown and needed to determine the collection surface area of both Langmuir probes
Testing Plan: Science – Langmuir Probe

• All regulation and bias circuitry will be simulated using EDA software, prototyped on a breadboard, and then tested on a PCB. This will minimize the possibility of circuits behaving unexpectedly, or outright failing.
• Once the power supply circuitry has been confirmed to work the driver for the Langmuir probe will be powered up on the bench.
• Once it has been powered the system will be commanded by a stand-in for the flight computer to set a fixed bias on the probe. The bias will be measured to ensure that it is within operating specifications.
• If the Langmuir probe passes the previous tests, it will be used to collect data in an in lab plasma chamber to verify the measurement accuracy.
• The engineering model of the Langmuir probe will then be integrated into the engineering model of the payload, and again tested with a plasma chamber.
Total Electron Count (TEC)
Total Electron Count (TEC): System changes since PDR

- Using a microcontroller to digitize all four analog TEC lines and encode for one assigned analog data line
- Collecting data from the SDR TEC at a rate of 500 Hz
- Using an active antenna design as to best match the circuit
- Antenna will deploy based on a timed event line
Total Electron Count (TEC): Detailed weight budget

<table>
<thead>
<tr>
<th>Mass*</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog TEC</td>
<td>&lt; 500 g</td>
</tr>
<tr>
<td>SDR TEC</td>
<td>&lt; 500 g</td>
</tr>
<tr>
<td>Antennas</td>
<td>&lt; 720 g</td>
</tr>
<tr>
<td>Total</td>
<td>&lt; 1720 g</td>
</tr>
</tbody>
</table>

* Accounts for mechanical hardware
## Total Electron Count (TEC): Detailed power budget

<table>
<thead>
<tr>
<th></th>
<th>Voltage</th>
<th>Power Requirement</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog TEC</td>
<td>7 - 20 V</td>
<td>&lt; 0.8 W</td>
<td>Analog Signal (Digitally Processed)</td>
</tr>
<tr>
<td>SDR TEC</td>
<td>5 V</td>
<td>&lt; 2.5 W</td>
<td>UART</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>&lt; 3.3 W</td>
<td>-</td>
</tr>
</tbody>
</table>
Total Electron Count (TEC): Software Design

Start → Read 1.3 MHz Record in buffer → Read 2.2 MHz Record in buffer → Read 3.338 MHz Record in buffer → Read 7.835 MHz Record in buffer → Interval a multiple of 30?

- No \ Interval++
  - Record min and max data point indices
  - Create derivative array from 1.3 MHz buffer
  - Create buffer with (4) max values followed by (4) min values
  - Transmit to DAC IC via SPI

- Yes \ No action taken

No \ Interval++

Yes \ No action taken
Total Electron Count (TEC): Schematic of Analog TEC

- Length: 113 mm
- Width: 77 mm
- Height: 22 mm

TI TLC5615
Arduino Micro
Total Electron Count (TEC): Schematic of SDR TEC

Awaiting contact from Masters student Stephen Lovas.
Total Electron Count (TEC): Schematic of Ground Station

Antenna 1 Num=1
Amplifier AMP1
VCO VCO1 Freq=1.3 MHz

Antenna 2 Num=2
Amplifier AMP2
VCO VCO2 Freq=2.2 MHz

Antenna 3 Num=3
Amplifier AMP3
VCO VCO3 Freq=3.883 MHz

Antenna 4 Num=4
Amplifier AMP4
VCO VCO4 Freq=7.835 MHz
Total Electron Count (TEC): Mechanical and Electrical Interfaces

**Mechanical**
- Mounting for Devices
  - Screws, bolts, etc.
- Antennas
  - 2pcs 1.5m pieces of measuring tape

**Electrical**
- Antenna connectors/Cables
- Data connection to CDH from both TEC’s
- Power for both TEC’s
Total Electron Count (TEC): Antenna Design
Active antenna circuit design:
Using op amp: AD8421
## Total Electron Count (TEC): Risk Matrix

<table>
<thead>
<tr>
<th></th>
<th>Negligible</th>
<th>Marginal</th>
<th>Critical</th>
<th>Catastrophic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Probable</strong></td>
<td>Antennas bend under shearing force</td>
<td>Interference from other payloads</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Possible</strong></td>
<td></td>
<td></td>
<td>Interference from other subsystems</td>
<td>Antennas Eject Prematurely</td>
</tr>
<tr>
<td><strong>Improbable</strong></td>
<td>Unforeseen error in code</td>
<td>Microcontroller memory wiped or otherwise inhibited</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Total Electron Count (TEC): Prototyping

- We are currently in possession of a retired analog TEC which has been characterized and will be used as a model for our flight model.
- The SDR TEC will have a standard 50 Ohm nominal impedance.
- The impedance of the antenna is very low due to the size limitations. To better match the impedance to the TEC’s, we will be utilizing an active antenna design.
- The active antenna will utilize an Op-Amp running in a voltage follow circuit. When simulated, this resulted in a maximum loss of -36dB from the antenna to the SDR TEC. This will further be fixed by the SDR’s internal amplifier.
- This design will assist in both TEC systems receiving the maximum power possible, which should return a higher resolution of data.
Total Electron Count (TEC): Prototyping Plans

- After the SDR TEC design is done we’ll be assembling and testing it on the bench before integrating it into a PCB
- The analog TEC will also be tested before being soldered onto PCBs
- Enclosures will be modeled for each TEC and then 3D printed to check for fit
  - Then each enclosure will be constructed in the shop out of metal as needed for the final design
Total Electron Count (TEC): Testing Plans

- Each instrument (analog, SDR) will be tested individually to ensure functionality
- Microcontroller will be tested thoroughly to ensure accuracy and number of data points matches that of the SDR TEC (analog)
  - This will directly ensure our requirement of equal number of datapoints
- Components will be assembled in enclosures that resemble their final design and re-tested
Total Electron Count (TEC): Prototyping and Analysis

- Each TEC and ground station will be tested in an environment similar to that which will be experienced in Norway (likely a large remote field)
  - This will fulfill our requirements that the ground station must transmit at the required power for the rocket to receive an usable signal
Lidar
Lidar: System Overview

• Novel lidar system will be used to make observations of neutral atmospheric dynamics.
  – System is similar to that developed by Eriksen and Hoppe et al in 1999
• Backscatter profile provides information on aerosols and neutral turbulent structures in the vicinity of the rocket
• Measurements will be made at a range no greater than 10 meters and no less than 2 meters
Lidar: System Changes Since PDR

- Laser diode power lines will be a timed event pin. This will help to guarantee eye safety
- Receive aperture has been switched from offset paraboloids to a Cassegrain reflector
Lidar: Concept of Operations
Lidar: System Block Diagram
Lidar: Transmitter

- Transmitter circuit is built around the Team Wavelength WLD3343 laser diode driver, and the OSRAM PLP B450 LD 450nm 1.6W Blue Laser Diode
- The full transmitter will utilize three of the above for a maximum optical output power of 4.8W.
- To ensure eye safety on the ground the diode drivers will be powered off a timed event pin triggered during flight.
- Schematic on next page
Lidar: Transmitter Schematic
Lidar Receiver

• The receiver is built around a Hamamatsu multi-pixel photon counter (MPPC)
• Biasing of the detector will be done through a biasing integrated circuit available from Hamamatsu
• Schematic is on the following slide
Lidar: Detector Schematic
Control and coordination will be accomplished through the use of a supervisory microcontroller.

- Will be based around Teensy 3.2 development board
- We have substantial experience prototyping with this board

Will act as an intermediary between CDH and the receiver and transmitter
Lidar: Optical Schematic

- Receiver optics are built around a classical Cassegrain telescope. We will utilize an approximately 3in diameter primary reflector.
- Using a Cassegrain architecture minimizes the physical size of the system, as well as the number of surfaces needed
- After the receive aperture the light will be passed through an interference filter, and then focused onto the detector.
## Lidar: Power and Mass Budgets

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (kg)*</th>
<th>Power (W)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter (3 diodes)</td>
<td>0.09</td>
<td>23.4</td>
</tr>
<tr>
<td>Detector</td>
<td>0.02</td>
<td>.25</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>0.02</td>
<td>4</td>
</tr>
<tr>
<td>Optics</td>
<td>2.00</td>
<td>NA</td>
</tr>
<tr>
<td>Mounting hardware</td>
<td>2.00</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.13</strong></td>
<td><strong>17.25</strong></td>
</tr>
</tbody>
</table>

*25% margins included
# Lidar Risk Matrix

<table>
<thead>
<tr>
<th></th>
<th>Negligible</th>
<th>Marginal</th>
<th>Critical</th>
<th>Catastrophic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Probable</strong></td>
<td>Transmitted wavelength changes with temperature variation during launch</td>
<td>In band interference from auroral, or man-made optical phenomenon</td>
<td>Laser diodes are burned out due to an overcurrent event</td>
<td></td>
</tr>
<tr>
<td><strong>Possible</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Improbable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Microcontroller communication to CDH is disrupted due physical disconnection</td>
<td>Laser diodes are not powered on due to error in triggering timed event; Structural failure of lidar</td>
</tr>
</tbody>
</table>
Lidar: Interface Description

• Will utilize locking D-Sub connectors for all power and data connections.

• System will be self-contained within a box. The box will have five threaded mounting holes to mount to the payload base. All mechanical connections will be secured with Loctite Red thread locker.
What needs to be finalized

• Resistor values for the comparator circuit need to finalized. These will be tuned based on the output of the MPPC that we are using.

• Exact dimensions of the receiver optics needs to be finalized. We know the diameter that we have to work with, but tuning the radius of curvature and focal length will be done.

• Structure needs to be finalized. It is highly dependent on the receive aperture and optical configuration.
Lidar: Testing Plan

- All regulation and bias circuitry will be simulated using EDA software, prototyped on a breadboard, and then tested on a PCB. This will minimize the possibility of circuits behaving unexpectedly, or outright failing.
- The laser diode driver will be simulated using EDA software, prototyped on a breadboard, and then tested on a PCB. The output of the driver will be tested to characterize any transients of the driver, and to verify that it's able to maintain the correct output.
- The laser diode will be connected to the driver and the output power of the laser will be measured. This will ensure that non-functional laser diodes are not used in the instrument.
- The bias circuitry for the detector will be measured on the bench to ensure that it has been programmed correctly and that the output is as anticipated.
- The detector will be connected to bias and amplification circuitry, and then tested in a low light environment to avoid saturating the receiver.
- The optical system will be first tested on an optical bench to verify that the receive aperture properly focuses incident light onto the detector. The field of view of the receive aperture will also be verified.
- Once separate components are tested, the lidar system will be integrated and tested on the ground. Neutral density filters will be used to mimic the number density of scatterers in the mesosphere. This will be used as a gauge of the validity of the measurements.
Attitude Determination
Subsystem Design: Attitude Determination

• Intended goal: achieve attitude knowledge to within 1 degree.
• Collect and sensor data during flight
  – Sun sensor angles
  – Magnetic field vector
  – Angular rates (MEMS gyro)
• Perform real time attitude determination with microcontroller
  – Use extended kalman filter with an attitude kinematics model.
  – “Attitude Estimation for Sounding Rockets Using Microelectromechanical System Gyros” (Bekkeng et al.) demonstrated that knowledge requirements could be met using this method with commercial grade components with similar properties to the components chosen here.
  – Use TRIAD for initial estimate to help with convergence
Subsystem Design: Attitude Determination

- Microcontroller
  - An intermediate microcontroller will be used for the attitude determination calculation
  - A four value quaternion attitude representation will be sent to CDH through an I2C interface
  - STM32F205RET6 Manufactured by STMicroelectronics
## Risk Matrix: Attitude Determination

<table>
<thead>
<tr>
<th></th>
<th>Negligible</th>
<th>Marginal</th>
<th>Critical</th>
<th>Catastrophic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Probable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Possible</strong></td>
<td>Uncharacterized behavior causes attitude error outside of 1 degree</td>
<td>Sun Sensor Pinhole becomes wholly or partially plugged</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Improbable</strong></td>
<td>Kalman Filter Fails to converge.</td>
<td>Launch shifts the sensor positions creating larger in flight biases</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Subsystem Design: Attitude Determination

• OSIRIS 3U Sun Sensors
  – Heritage with OSIRIS 3U Cubesat
  – ADS1115 ADC
  – S5990-01 PSD

• Magnetometer
  – HMC5883L

• Rate Gyros
  – MPU-6050

• Voltage Regulators
  – L7815CV
  – L7805CV
  – L78L33ACUTR
  – Microcontroller
  – STM32F205RET6
Subsystem Design: Attitude Determination
### Subsystem Design: Attitude Determination

<table>
<thead>
<tr>
<th>Part</th>
<th>Component</th>
<th>Power</th>
<th>Weight</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Sensor</td>
<td>Sun Sensors</td>
<td>60 mW</td>
<td>22.8 g</td>
<td>$400</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>HMC5883L</td>
<td>0.3 mW</td>
<td>18 mg</td>
<td>$10</td>
</tr>
<tr>
<td>Rate Gyroscope</td>
<td>MPU 6050</td>
<td>12 mW</td>
<td>20 mg</td>
<td>$15</td>
</tr>
<tr>
<td>15 V regulator</td>
<td>L7815CV</td>
<td>78 mW</td>
<td>2.3 g</td>
<td>$0.55</td>
</tr>
<tr>
<td>5 V regulator</td>
<td>L7805CV</td>
<td>138.6 mW</td>
<td>2.3 g</td>
<td>$0.44</td>
</tr>
<tr>
<td>3.3 V regulator</td>
<td>L78L33ACUTR</td>
<td>241.7 mW</td>
<td>0.13</td>
<td>$0.42</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>STM32F205RET6</td>
<td>161 mW</td>
<td>2 g</td>
<td>$10.52</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>691.6 mW</td>
<td>27.5 g</td>
<td>$437</td>
</tr>
</tbody>
</table>
Testing Plan: Attitude Determination Software

- ADS Software
  - Attitude software will be written in C and run on desktop computers. This software will simulate inputs from all sensors to verify that the Kalman filter works and converges.
  - Identical software will be loaded onto the microcontroller to verify that the software runs in this environment. This software will simulated inputs rather than real hardware inputs.
  - The attitude sensors will then be connected to verify that the Kalman filter works and converges using real data taken from flight hardware.
  - This software will then be loaded onto the engineering model of the payload to verify that it works in flight
Testing Plan: Attitude Determination Hardware

- **Magnetometer**
  - **Functionality**: An Arduino will be used to test the functionality of the magnetometer. The Arduino will power the magnetometer and provide an I2C port. The data will be read to the serial output and connected to a desktop. A user will then check that the values output match the local magnetic field.
  - **Noise and Bias Characterization**: An Arduino will be used to test the noise and bias in the Magnetometer. The Arduino will power the magnetometer and provide an I2C port. The data will be read to an SD card rather than directly to a desktop. The magnetometer will be placed in a Helmholtz cage which will null the local magnetic field. The data will then be analyzed to characterize the noise and bias inherent in the sensor.

- **Gyroscope**
  - **Functionality**: An Arduino will be used to test the functionality of the gyroscope. The Arduino will power the gyroscope and provide an I2C port. The data will be read to the serial output and connected to a desktop. The gyroscope will be set on a still surface. A user will then check that the magnitude of the values match the earth’s spin rate.
  - **Polarity**: Using the same setup as the functionality test, the user will rotate the sensor about all three axes and verify that the rotation direction matches the output of the sensor.
Testing Plan: Attitude Determination Hardware

• Gyroscope (Continued)
  • Noise and Bias Characterization: An Arduino will be used to test the noise and bias in the gyroscope. The Arduino will power the gyroscope and provide an I2C port. The data will be read to an SD card rather than directly to a desktop. The gyro will be placed on a spin table and spun at the nominal rate after despin of 0.2 rad/s. The data will then be analyzed to characterize the noise and bias inherent in the sensor.

• Sun Sensor
  • Functionality: An Arduino will be used to test the functionality of the Sun Sensors. The Arduino will power the sun sensor and provide an I2C port. The data will be read to the serial output and connected to a desktop. The gyroscope will be set under a light apparatus in the lab. A user will check that the output values match the angle set by the light apparatus.
Structures
System Updates since PDR

- Developing method to deploy langmuir booms (2) and TEC antenna
- Analyzing stresses that payload will be under during mission
- Compliance with users guide
  - Physical inhibit
  - COG requirement
  - Mass requirement
Stress/Strain Analysis

- Von Mises stress experienced during flight. Stresses will be concentrated on the fixed points of the deck. Thus, further support at these points may be required.
Stress/Strain Analysis

- Displacement heat map showing that the greatest amount of displacement of the deck will be in the middle due to the 490 N compressive force during flight. Maximum deflection that will be expected is approx 0.1407 mm
Stress/Strain Analysis

- Strain analysis heat map in agreement with the stress analysis showing most strain will be concentrated at the fixed points.
Center of Gravity

• Layout since PDR updated and a counter balance added (2 kg) due to center of gravity outside of required one inch circle

• Model of center of gravity of each component plotted taking into account the masses of each deck component plus the mass of deck itself. COG is black dot shown within the 1 inch circle requirement.
Deployment method

• Burn wire mechanism
  – Booms made of tape measure
  – Prior to launch and deployment, the tape measures will be coiled up and held in place by a string
  – Nichrome wire will be attached to the string on each end
  – Deployment is initiated by a timed event that sends current through the nichrome wire subsequently burning the string and uncoiling the tape measure

• Prototype deployment speed
  – 13.39 in/s
Deployment Physical Inhibit

- CAD model of physical inhibit design for langmuir probe shown on the right
- Physical inhibit design for TEC antenna is the same, but dimensions are different
Testing Plan: Structures

• Langmuir Probe Deployment:
  • Burn wire mechanism will be prototyped on a breadboard to verify functionality. This will minimize the possibility of a failed deployment due to burn wire failure.
  • Dry run deployment will be tested on a stand-in for the payload bay. This will minimize the risk of a failed deployment due to mechanism failure.
  • Vibration testing will be conducted in accordance with those specified in the RS-XN user guide to minimize the possibility of an accidental deployment of the Langmuir probe.
  • Once vibration tested, the deployment mechanism will be tested again to verify that it is still functional after experiencing vibration similar to launch.

• Payload Mounting:
  • Finite element analysis will be conducted on a SolidWorks model of the integrated payload to identify potential areas of mechanical stress. This will minimize the possibility of the payload bay or instruments becoming damaged during travel and stowing.
  • Vibration testing on an engineering model of the payload will be conducted in accordance with the specifications of the RS-XN user guide to minimize the possibility of instruments or subsystems becoming displaced.
4D System
System Update: 4D System

- Met with UiO to discuss collaboration
  - Held Skype meeting with Ketil Røed
  - Discussed current and future goals of the venture
System Update: 4D System

- **Deliverables**
  - Characterize both the antenna on the rocket and the antenna on the daughters
  - Investigate improvements to antennas and further communication options
Testing

• Anechoic chamber had to be calibrated and tested to confirm expected results are accurate
Results

• A first round of characterization for the antenna on the daughters has been accomplished.
Science: 4D System Antenna

- The antenna will be designed and simulated using electromagnetics modeling software such as CST or HFSS. This will verify that the antenna will theoretically resonate at the intended frequency, and that the radiation pattern is correct.
- The antenna will then be fabricated with tuning stubs where appropriate
- S11 and VSWR measurements will then be conducted on the antenna. This will ensure that the antenna is resonant at the correct frequency.
- If needed adjustments will be made via the tuning stubs. This will correct for any errors between simulation and fabrication.
- The antenna will then be tested in Penn State’s anechoic chamber. This will verify that the antenna has the proper radiation pattern.
- Once antenna parameters are confirmed, the antenna will be simulated again with the appropriate modifications.
- The newly simulated antenna will then be constructed. Following that S11 and pattern measurements will be taken.
5.0 Manufacturing Plan

Stephen Porter, Erica Venkatesulu
Mechanical Elements

- What will be manufactured?
  - Housings for subsystems
  - Boom deployment mechanisms (depending on complexity)
- What will be purchased?
  - Mounting hardware (nuts, bolts)
  - Boom material (tape measures)
- Task completion schedule
  - February 2: CAD models for manufacturing. Purchase other parts.
  - March 2: Print models and make changes.
  - April 6: Fabricate using primarily aluminum
  - May 4: Subject to in-house tests, make final mods
Electrical Elements

• What needs to be manufactured/soldered?
  • All subsystems will need PCBs except structures, CDH.
  • Most boards will be assembled at Penn State, complex ones done professionally. May professionally conformal coat.

• How many revisions do you anticipate?
  • 2 (Designs will be reviewed by a professional before order)

• What needs to be procured?
  • Electrical components, PC boards, conformal coating

• Task completion schedule
  • February 2: Complete design of all PC boards, review/revise
  • March 2: Order, receive, and test individual boards. Design changes
  • April 6: Order, receive, and test new boards (subsystem level)
  • May 4: Continue testing, integrate to system level
Software Elements

• Task completion schedule
  • February 2: Write high-level functions, test
  • March 2: Write low level functions, test
  • April 6: Subsystem testing
  • May 4: System testing

• Dependencies
  • Transmission code relies on correct receive code
7.0 User Guide Compliance

Name of Presenter
# User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; plane of plate?</td>
<td>YES (CAD model)</td>
</tr>
<tr>
<td>Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs.?</td>
<td>YES (Mass budget)</td>
</tr>
<tr>
<td>Max Height &lt; 10.75” (5.13”)</td>
<td>YES</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>N/A, Bottom-mid mount used</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>YES (SolidWorks model)</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>YES, using 4</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>YES</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>YES, at 76800 baud</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
<td>GSE-1, GSE-2</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>TE-1, TE-2, TE-3</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>YES</td>
</tr>
<tr>
<td>Using &lt; 1 Ah</td>
<td>YES (Power budget)</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>YES</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>NO, but receiving signal from ground of 1.3 MHz, 2.2 MHz, 3.883 MHz, 7.835 MHz (is it more apt to say measure signal strength of...?)</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>YES</td>
</tr>
<tr>
<td>Whole team consists of US Persons</td>
<td>NO</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>NO</td>
</tr>
</tbody>
</table>
User Guide Compliance: Power Interface

<table>
<thead>
<tr>
<th>Power Connector--Customer Side</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pin</strong></td>
<td><strong>Function</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GSE-1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TE-RA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TE-RB</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TE-1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>GSE-2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>TE-2</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>TE-3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GND</td>
<td></td>
</tr>
</tbody>
</table>

- USE Pin Assignment xls file
- Include a screenshot in your presentation and the actual excel file with your CDR package
- Fill-in the function side for your payload
- Check for consistency with User’s Guide
User Guide Compliance: Telemetry Interface

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>20</td>
<td>Parallel B7</td>
</tr>
<tr>
<td>2</td>
<td>A2</td>
<td>21</td>
<td>Parallel B8</td>
</tr>
<tr>
<td>3</td>
<td>A3</td>
<td>22</td>
<td>Parallel B9</td>
</tr>
<tr>
<td>4</td>
<td>A4</td>
<td>23</td>
<td>Parallel B10</td>
</tr>
<tr>
<td>5</td>
<td>A5</td>
<td>24</td>
<td>Parallel B11</td>
</tr>
<tr>
<td>6</td>
<td>A6</td>
<td>25</td>
<td>Parallel B12</td>
</tr>
<tr>
<td>7</td>
<td>A7</td>
<td>26</td>
<td>Parallel B13</td>
</tr>
<tr>
<td>8</td>
<td>A8</td>
<td>27</td>
<td>Parallel B14</td>
</tr>
<tr>
<td>9</td>
<td>A9</td>
<td>28</td>
<td>Parallel B15</td>
</tr>
<tr>
<td>10</td>
<td>A10</td>
<td>29</td>
<td>Parallel B16 (LSB)</td>
</tr>
<tr>
<td>11</td>
<td>Parallel B1 (MSB)</td>
<td>30</td>
<td>Parallel Read Strobe</td>
</tr>
<tr>
<td>12</td>
<td>Parallel B2</td>
<td>31</td>
<td>N/C</td>
</tr>
<tr>
<td>13</td>
<td>Parallel B3</td>
<td>32</td>
<td>RS-232 Data</td>
</tr>
<tr>
<td>14</td>
<td>Parallel B4</td>
<td>33</td>
<td>RS-232 GND</td>
</tr>
<tr>
<td>15</td>
<td>Parallel B5</td>
<td>34</td>
<td>N/C</td>
</tr>
<tr>
<td>16</td>
<td>Parallel B6</td>
<td>35</td>
<td>N/C</td>
</tr>
<tr>
<td>17</td>
<td>N/C</td>
<td>36</td>
<td>GND</td>
</tr>
<tr>
<td>18</td>
<td>GND</td>
<td>37</td>
<td>GND</td>
</tr>
<tr>
<td>19</td>
<td>GND</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- USE Pin Assignment ICD xls file
- Fill-in the function side for your payload
- Include a screenshot in your presentation and the actual excel file with your CDR package
- Check for consistency with User’s Guide
8.0 Project Management Plan (PMP)

Stephen Porter, Erica Venkatesulu
PMP: Organizational Chart

PAWSS

Co-PI's
Tim Wheeler
Dr. Sven Billen
Dr. Tim Kane

Project Manager
(S. Porter, E. Venkatesulu)

Systems Engineers
(S. Hixon)

Payload

Lead
A. Guerra

Lead
N. Smith

Lead
M. Miller

Lead
S. Krupa

AD
CDH
PWR
STR

Scientific Payload

Cog. Engineer
R. Martin, S. Foley

Cog. Engineer
A. O'Neill

Cog. Engineer
S. Numan

TEC TX/RX
Lidar
Langmuir Probe
PMP: Team Picture
PMP: Monetary Budget

• Required funding
  – Hardware - $35,000
  – Travel (U.S. and Norway) $40,000
  – Program fee - $25,000

• Funding Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
<th>Purpose</th>
<th>Status</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GELP Grant</td>
<td>25,000</td>
<td>Travel</td>
<td>Acquired</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Corporate</td>
<td>10,000</td>
<td>Hardware</td>
<td>In progress</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PA SGC</td>
<td>10,000</td>
<td>Hardware, U.S. travel</td>
<td>In progress</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PSU EE</td>
<td>5,000</td>
<td>Hardware</td>
<td>Acquired</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Waived</td>
<td>25,000</td>
<td>Program Fee</td>
<td>Acquired</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>75,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### PMP: Latest 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>Project Manager</td>
<td>Stephen Porter</td>
<td>412-228-1656</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:sjp5556@psu.edu">sjp5556@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Principal Investigator</td>
<td>Prof. Tim Wheeler</td>
<td>814-863-5403</td>
<td></td>
<td></td>
<td><a href="mailto:G-Chaser@psu.edu">G-Chaser@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Principal Investigator</td>
<td>Dr. Sven Bilen</td>
<td>814-863-1526</td>
<td></td>
<td></td>
<td><a href="mailto:SBilen@engr.psu.edu">SBilen@engr.psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Principal Investigator</td>
<td>Dr. Tim Kane</td>
<td>814-863-8727</td>
<td></td>
<td></td>
<td><a href="mailto:tjk7@psu.edu">tjk7@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Systems Engineer</td>
<td>Sean Hixon</td>
<td>412-915-7236</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:sxh5594@psu.edu">sxh5594@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Veronica Petrus</td>
<td>814-691-1998</td>
<td></td>
<td></td>
<td><a href="mailto:vlp5117@psu.edu">vlp5117@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Science - Lead</td>
<td>Al Guerra</td>
<td>954-592-3432</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:alvaro@psu.edu">alvaro@psu.edu</a></td>
<td>US</td>
<td>Yes</td>
</tr>
<tr>
<td>Lidar - Lead</td>
<td>Andrew O'Neill</td>
<td>610-880-1070</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:ajo5182@psu.edu">ajo5182@psu.edu</a></td>
<td>US</td>
<td>Yes</td>
</tr>
<tr>
<td>TEC - Lead</td>
<td>Scott Foley</td>
<td>570-688-7011</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:saf5411@psu.edu">saf5411@psu.edu</a></td>
<td>U.S.</td>
<td>yYes</td>
</tr>
<tr>
<td>TEC - Lead</td>
<td>Rob Martin</td>
<td>570-690-4475</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:rfm5313@psu.edu">rfm5313@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Langmuir - Lead</td>
<td>Sebastian Niuman</td>
<td>(786) 208-2160</td>
<td></td>
<td>Yes</td>
<td><a href="mailto:sjn5202@psu.edu">sjn5202@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>4D - Lead</td>
<td>Jeremy Mysliwiec</td>
<td>610-858-3512</td>
<td></td>
<td>yes</td>
<td><a href="mailto:jnmysliwiec@gmail.com">jnmysliwiec@gmail.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power - Lead</td>
<td>Matt Miller</td>
<td>315-414-7719</td>
<td></td>
<td>yes</td>
<td><a href="mailto:mdm5857@psu.edu">mdm5857@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Command and Data Handling - Lead</td>
<td>Nick Smitj</td>
<td>610-739-6953</td>
<td></td>
<td>yes</td>
<td><a href="mailto:njs5393@psu.edu">njs5393@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Guidance Navigation and Control - Lead</td>
<td>Ryan Stashko</td>
<td>570-854-1530</td>
<td></td>
<td>yes</td>
<td><a href="mailto:rjs5827@psu.edu">rjs5827@psu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
## PMP: Team Availability Matrix

### PDR RS-XN Team Availability Matrix

**PLEASE USE MOUNTAIN TIME ZONE TIMES**

<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>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
PMP: Worries

• Spark gap interference
• Sweeping Langmuir Probes on other payloads may negatively effect rocket potential
• Guide-specified boom deployment rate too slow, must exceed
• Rocket design unknowns causing payload design difficulties
PMP: Conclusions

• Address why your mission deserves to fly
  – Science design anticipates valid scientific return
  – Hardware verification an objective
  – Involves students from all years and many majors

• Next steps for your team to get to STR (Subsystem Testing Review)
  – Complete subsystem design
  – Begin ordering and testing real hardware
  – Delta CDR may be valuable once changes based on finalized rocket design are integrated
9.0 Appendix
Mission Overview: Theory and Concepts

• Mission: To contribute to understanding of the cause(s) of Polar Mesosphere Winter Echoes (PMWEs).

• The two most plausible explanations deal with electron density and neutral non-homegenity.

• We will use instruments aboard G-Chaser to collect measurements and compare its data to a ground radar devoted to measuring PMWEs during the experiment.
Mission Overview: Expected Results

• The PAWSS team expects to see relative neutral density and lidar backscatter to follow the profile measured by Erickson, Hoppe, Thrane, and Blix in their 1999 investigation of a rocket based lidar system.

• If neutral turbulence is present, we expect perturbations in the backscatter profile.

• If aerosols are present, we expect to see a marked increase in the backscatter profile.
Mission Overview: Expected Results

• In case of low solar activity, the PAWSS team expects to see the electron density profile to follow the profile measured by V. Barabash et al., 2012 through rocket experiments.

![Graph showing electron density profile](image-url)
Mission Overview: Expected Results

- PAWSS team expects an enhanced level of electron density in the case of a PMWE event.
- The team expects the fixed bias Langmuir probe to detect electron density fluctuations of the scale ~3m in case of a PMWE event at about 50-80 km.
- The team will also expect an enhanced electron density fluctuations in case of turbulence.
## Top Level Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The payload shall interface with the provided connections on the rocket to</td>
<td>Demonstration</td>
<td>Testing operations at PSU and at NASA Wallops will verify functionality.</td>
</tr>
<tr>
<td>receive power and send telemetry.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The instrument systems shall collect and format valid data for transmission</td>
<td>Analysis and Testing</td>
<td>Testing operations and analysis at PSU and at NASA Wallops will verify</td>
</tr>
<tr>
<td>by the rocket to the ground.</td>
<td></td>
<td>functionality.</td>
</tr>
<tr>
<td>The system shall be designed to meet all structures requirements defined</td>
<td>Inspection, Analysis, and</td>
<td>Testing operations and calculations at PSU and at NASA Wallops will verify</td>
</tr>
<tr>
<td>in the RockSat-X program (keep out zones, weight and center of gravity</td>
<td>Testing</td>
<td>functionality.</td>
</tr>
<tr>
<td>requirements, etc)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>