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  – Budget
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  – Work Breakdown Structure
Mission Overview

Avery Wimbrow
Azael Roa
Mission Overview

Mission Statement: To capture in-flight data from a transistor tester for faculty research, navigation and orientation data via gyroscope and accelerometer, as well as capturing communications with an on board receiver and processing data with an Software Defined Radio. Additionally, we would incorporate vital sensors with intent to improve upon our last payload design and continue the integration of a small form-factor experiment to allow other students or groups to fly small experiments on RockSat-C missions.
Mission Overview

• Primary payload:
  – Test experimental transistor circuit under launch conditions
  – Test reliability of Software Defined Radio (SDR) receiver

• Secondary payload:
  – Vital sensors (3 axis accelerometer & gyroscope)
  – Geiger counter
  – Partner High school experiment
Mission Overview: Mission Objectives

• Project requirements
  – Must collect and store I-V data from GaN HEMT
  – Must be able to detect alpha particles, beta particles, and gamma rays
  – Must accurately produce and store navigational data
  – Must be able to detect radio frequencies in broad spectrum (300 MHz to 1 GHz or higher), requiring access to multipurpose port
  – Needs a two SMA-port to host two antennas.
Mission Overview: Theory and Concepts
Software Defined Radio

- Like traditional radio but instead of using several pieces of purpose built hardware (like filters, modulators, etc.) it digitizes the received signal and uses digital signal processing to decode the received signal
- This has a lot advantages over traditional radio, but for our experiment it can give us a broader view of the radio spectrum than would otherwise be possible
Mission Overview: Theory and Concepts

GaN HEMT Transistor

- Field Effect transistor with a junction between two different bandgap materials
- Used in cell phones, communications devices, and other high frequency integrated circuits as a switch
- Able to operate at much higher frequencies compared to other FETs and exhibit low noise characteristics
- We expect to have little change in gain characteristics due to high energy particles
Mission Overview: Theory and Concepts

Geiger Counter

- A tube filled inert gas with electrodes at both ends with a voltage applied. When exposed to ionizing radiation a current is generated. Current generated is proportional to the amount of radiation.
- We are flying a transistor that most likely have different gain characteristics when exposed to different amount of ionizing radiation.
- We expect to detect significantly more radiation in the flight than on the ground.
Mission Overview: Theory and Concepts

Inertial Navigation Sensor System

- Accelerometer and Gyroscope combination which by responding to stress, provides G-Force measurements throughout the flight.
- High-G accelerometer will be used to measure changes in the Z-axis (perpendicular to Earth) while 3-axis gyroscope will be used for X and Y.
- Provides time stamped measurements on flight characteristics which may be used to identify points of interest in flight for use with the other devices measurements.
Mission Overview: Concept of Operations

- Data will be recorded throughout the entire mission
  - The altitude at apogee will produce the greatest endurance test for this experiment concerning RF communications and transistor IV delta
  - Maximum acceleration forces will be realized at launch and burnout stages of the flight
  - Data will continuously collect and be recovered after splashdown
Mission Overview: Concept of Operations

- **Apogee**
  - $t \approx 2.88 \text{ min}$
  - Approx. 115 km
  - Highest Concentration of high energy particles expected

- **Skywave Region**
  - $t \approx 1.65 \text{ min}$
  - Approx. 90 km
  - Enter Ionosphere E Layer

- **High G Burnout**
  - $t \approx 0.1 \text{ min}$
  - Approx. 2 km
  - Spin rate increase

- **High Tumble Region**
  - $t \approx 4.0 \text{ min}$
  - Approx. 95 km

- **Chute Deployment**
  - $t \approx 5.5 \text{ min}$
  - Low Spin

- **Splashdown**
  - $t \approx 15.0 \text{ min}$
  - Continue data collection

- **T-3 min 1SYS.1 Activation**
  - Begin data collection
Mission Overview: Expected Results

- The IV characteristics of the transistor will see limited gain effects from ionizing radiation due to predicted low solar activity in the next solar cycle, and the limited activity in the location of the experiment in the ionospheric E layer (between 90 km - 140 km).

- We expect that the SDR will be able to process received data transmitted from a ground based source transmitting in the VHF band (30 MHz to 300 MHz) or UHF band (300 MHz to 3 GHz), where lower frequencies may be subject to ionospheric reflection. Other RF bands may be captured in addition to these, though will be limited by the antennae used and the Bandwidth of the SDR.

- From the gyroscope data we should be able to see between 5 and 6 Hz spin on the rocket and from the accelerometer we should see maximum acceleration magnitude of 25 G’s.

- We expect no interference between partner experiments.
Mission Overview: Expected Results

• Minimum success criteria
  – Store data for the first ten minutes of flight
  – Successful capture of data for transistor tester and received RF communications via software defined radio
  – Capture accelerometer data
  – Record and analyze data from Faculty device experiments
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDR shall be able to receive signals with the custom antennas</td>
<td><strong>Analysis</strong></td>
<td>The antennas shall be checked for compatibility with the antennas and tested for success</td>
</tr>
<tr>
<td>The transistor tester shall be able to generate IV curves</td>
<td><strong>Test</strong></td>
<td>The transistors shall be tested in order to ensure generation curves at rest in order to ensure operation in flight</td>
</tr>
<tr>
<td>The accelerometer and gyroscope shall be able to accurately capture the flight data</td>
<td><strong>Demonstration</strong></td>
<td>Once established in the system, a brief set of inertial measurements shall verify requirement</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration tests in a simulated environment before finalization</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
De-Scopes and Off-Ramps

- All payloads will be plug and play, meaning that components can be replaced easily in case of failure and we will try to fit two systems of every payload.
- In case, the ceramic port cover is not manufactured on time or does not withstand simulation, an Aluminum port cover will be used.
System Overview

Evan Somers
Avery Wimbrow
Theo Fessaras
System Definitions

Systems in payload:
1. Batteries and power (Power)
2. Software Defined Radio (SDR)
3. Gallium Nitride High Electron Mobility Transistor Tester (Transistor Tester)
4. Geiger Counter and its Voltage up converter (Geiger)
5. INSS - Accelerometer, Magnetometer, and Gyroscope (Accel.)
6. Printed Circuit Board (PCB)
Changes since PDR

- The expected band we capture may be limited to UHF due to limitation of antenna size
- Changing the pancake style Geiger Muller tube to traditional tube due to mechanical concerns
System Level Block Diagram

- HackRF SDR
- Raspberry Pi Zero
- Communications Receiver System
- Voltage Upconverter
- Voltage Regulator
- Lithium Batteries
- Power

Components:
- Teensy 4.0 control
- Accel.
- Gyro
- Magnetometer
- INSS
- Geiger Counter
- I-V Sense
- GaN Transistor
- Transistor Tester
- SD Memory
- Wallops PT Interface
- Lithium Batteries
System Design - Physical Model

- 9.3” across
- 4.75” Tall
Port Design - Physical Model

- A feed line is attached to the center of the bowtie antenna as a balun
- This will be fed through a teflon lined hole in the ceramic port cover, which will also be sealed with heat resistant epoxy
- The antenna board will be a thin FR4 substrate that will be both screwed into port cover holes and glued to the surface of our ceramic port cover with a heat resistant epoxy
Port Design - Physical Model

- The coax feed lines will be connected to the SMA connectors inside the port
- A secondary antenna will be inside the port
- The SMA connectors will then run additional coax feeds to the SDR input
Software Design Elements - Plan

Create code for:

- Teensy 4.0 (x2)
  - INSS (Accelerometer and Gyroscope integration)
  - Transistor tester
- Raspberry Pi Zero
  - SDR

Review and Test code from High School micropayload design
Software Design Elements - Major Functions

Teensy 4.0:
- Write to SD card - Take input data and write neatly to file for post-launch processing
- Collect G-Force data - Take output measurements from accelerometer sensor to send to SD card
- Collect System data - Take output measurements from gyroscope sensor to send to SD card
- Generate Transistor data - Collect I-V data from testing transistors to send to SD card

Raspberry Pi Zero:
- Process Signal - Take RF reception data from antenna and process for recording
Software Design Elements - Flow

Teensy 4.0 → Develop code for 3-Axis accelerometer → Develop code for Gyroscope → Test and debug use of both sensors together

Teensy 4.0 → Develop code for transistor tester → Test and debug use of transistor tester with actual measurements

Raspberry Pi Zero → Integrate code for SDR → Test and debug with test signals
Software Design Elements - INSS Schematic

Using I2C configuration
NOTE: Only pins represented are the pins used. Power and ground will be shared between sensors
Design Overview: Shared Can Logistics

- We will share the canister
  - Half of the canister will go to the University of Delaware physics department
    - Their project will be a langmuir probe
- Collaboration
  - We will communicate via email
  - Designs (and all other files) will be stored in a drive they will have access to
- Canister Volume Allocation
  - Our project is deliberately designed to work in either half of the canister
  - Neither of our projects will weigh very much so our project will have space for ballast
- Port needs
  - Both teams need a multipurpose port
Subsystem Design

Avery Wimbrow
Azael Roa
Theodore Fessaras
Evan Somers
Subsystem Design: INSS Block Diagram

- **Power** -> +5.0 V
- **Teensy 4.0**
  - CLK out
  - Data -> +3.3 V
- **3 axis Gyroscope**
  - 3 axis Accelerometer
  - 3 axis Magnetometer
  - CLK out
- **SD Card**
  - Data
- **Single axis High-g Accelerometer**
  - Data
  - +3.3 V
INSS Characteristics

Voltage: 5 V  
Current Draw: 100 mA  
Estimated Total Area: 9 in^2  
Estimated Weight: 12.4 g  

Design is mostly finalized, system needs to be prototyped and tested for confirmation.
Subsystem Design: DUT 1 Block Diagram

- Power
- SD Card
- Teensy 4.0
- Current Sensing
- GaN HEMT

Connections:
- +5.0 V to Teensy 4.0
- Data from SD Card to Teensy 4.0
- Data from Teensy 4.0 to Current Sensing
- Data from Current Sensing to GaN HEMT
- Data from GaN HEMT to Teensy 4.0
- Data from Teensy 4.0 to V Step
- Data from V Step to Teensy 4.0
- Data from Teensy 4.0 to V Sweep
- Data from V Sweep to Teensy 4.0
## DUT 1 Characteristics

<table>
<thead>
<tr>
<th>Component</th>
<th>Voltage</th>
<th>Current Draw</th>
<th>Estimated Total Area</th>
<th>Estimated Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teensy 4.0</td>
<td>5 V</td>
<td>100 mA</td>
<td>1 in^2</td>
<td>7 g</td>
</tr>
<tr>
<td>LTC1655</td>
<td>5 V</td>
<td>1.6 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM324</td>
<td>9 V</td>
<td>0.5 mA</td>
<td>0.1 in^2</td>
<td>2 g</td>
</tr>
</tbody>
</table>
Subsystem Design: Transistor Tester
Subsystem Design: DUT 2 Block Diagram

- Power
- Memory
- Raspberry Pi Zero
- SDR
- Custom Antenna 1 Exterior
- Custom Antenna 2 Port mount
- Multipurpose Port with Ceramic Cover and SMA outputs

Power supply: +5.0 V
DUT 2 Characteristics

Raspberry Pi Zero:
Voltage: 5 V
Current Draw: 140 mA
Estimated Total Area: 3.12 in^2
Estimated Weight: 9 g

Hack RF One:
Voltage: 3.3 V
Current Draw: 50 mA
Estimated Total Area: 24 in^2
Estimated Weight: 226 g
Voltage controlled switch provides non-latching control of Power
Subsystem Design: Geiger Counter

Voltage across GM Tubes expected to be 450 V with current in microamps
<table>
<thead>
<tr>
<th>Mechanic al Failure</th>
<th>Power Failure</th>
<th>Power Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaN Device Failure</td>
<td>Fail to Capture RF</td>
<td>Fail to Capture RF</td>
</tr>
<tr>
<td>Coding Errors</td>
<td>INSS Failure</td>
<td>INSS Failure</td>
</tr>
</tbody>
</table>

### Possibility

- **Power Failure**
  - No data can be collected in the event of power failure
- **Mechanical failure**
  - Failure to secure devices or connections
- **RF Capture Failure**
  - Attenuation or interference results in limited or unusable data
- **Coding errors**
  - Coding errors causes system or data capture failure
- **Experimental GaN DUT Failure**
  - Wire bonding or device failure
## Mass Budget

<table>
<thead>
<tr>
<th>System</th>
<th>Mass</th>
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<tbody>
<tr>
<td>INSS</td>
<td>12.4 g</td>
</tr>
<tr>
<td>SDR</td>
<td>235.0 g</td>
</tr>
<tr>
<td>Transistor Tester</td>
<td>9.0g</td>
</tr>
<tr>
<td>Geiger</td>
<td>50.0 g</td>
</tr>
<tr>
<td>Power</td>
<td>350.0 g</td>
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</tbody>
</table>

**Total: 656.4 g or 1.45 lbs**
## Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSS</td>
<td>5.0</td>
<td>1.000E-01</td>
<td>30</td>
<td>0.50</td>
<td>0.050</td>
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<tr>
<td>SDR</td>
<td>5.0</td>
<td>1.730E-01</td>
<td>30</td>
<td>0.87</td>
<td>0.087</td>
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<tr>
<td>Geiger</td>
<td>500.0</td>
<td>5.000E-04</td>
<td>30</td>
<td>0.25</td>
<td>0.000</td>
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<tr>
<td>Transistor</td>
<td>9.0</td>
<td>1.000E-05</td>
<td>30</td>
<td>0.00</td>
<td>0.000</td>
</tr>
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<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>0.27</th>
<th>1.62</th>
<th>0.14</th>
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</thead>
<tbody>
<tr>
<td>Total Power Capacity</td>
<td>2.2</td>
<td>60</td>
<td>48.84</td>
<td>2.20</td>
</tr>
<tr>
<td>Over (+)/Under (-)</td>
<td># of Flights/Margin</td>
<td>7.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prototyping Analysis

Avery Wimbrow
Azael Roa
## Prototyping plan

<table>
<thead>
<tr>
<th>Device</th>
<th>Risks and Concerns</th>
<th>Actions</th>
</tr>
</thead>
</table>
| **1** Power Regulation        | 1. System failure due to turbulence  
2. Insufficient power distribution | 1. Shake test before finalization  
2. Test and measure power distribution |
| **2** Transistor Tester       | 1. System failure due to turbulence  
2. Failure to calculate IV characteristics at rest | 1. Shake test before finalization  
2. Test with multimeter |
| **3** Software Defined Radio  | 1. System failure due to turbulence  
2. Failure to receive signal  
3. Failure to write to memory | 1. Shake test before finalization  
2. Test transmission on ground at various ranges |
| **4** Accelerometer and Gyroscope | 1. System failure due to turbulence  
2. Failure to write to memory  
3. Incorrect calibration at rest | 1. Shake test before finalization  
2. Test on ground with simulated flight |
Current Prototyping Results

Teensy 4.0:
- Both devices tested successfully, able to write to SD card. No current concerns.

Geiger Counter:
- Pancake style tube was found to have risk of thin film rupture at high altitudes. Needs to be replaced with traditional style tube.
Manufacturing Plan

Avery Wimbrow
Azael Roa
Manufactured Elements

PCBs Required:

- Continue to test and breadboard power regulator
  - Develop board and send to PCB design house
- Testing and breadboarding Geiger and Transistor tester circuit
  - Develop board and send to PCB design house
- Continue testing and simulating antenna designs
  - Develop antenna PCB and send to PCB design house
- Hand solder boards

Expected lead times:

- 2-3 Weeks for two layer board orders
Software Elements

Code Blocks needed:

- Record and store inertial navigation data
- Record and store transistor tester data
- Write to SD card (for Teensy 4.0)
- Record and store SDR data (for Raspberry Pi Zero)

Only blocks that depend on each other are writing to SD card for Teensy and the recording of INSS/Transistor tester data.
### Software Plan/Schedule

<table>
<thead>
<tr>
<th>By Date Range</th>
<th>Software Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>By January 2020</td>
<td>Completion of preliminary INSS software</td>
</tr>
<tr>
<td>Jan. 1st - Feb. 1st</td>
<td>Completion of preliminary Transistor tester and SDR software</td>
</tr>
<tr>
<td>By March</td>
<td>Thorough testing and debugging of existing software</td>
</tr>
<tr>
<td>By April-May</td>
<td>Review High School micropayload software, check integration</td>
</tr>
</tbody>
</table>
Testing Plan

Avery Wimbrow
Azael Roa
Mechanical Testing

- Vibration Test on all Payloads
  - Test mechanical aptitude of systems at UD via vibration tests
- Test exterior mounted devices for mechanical aptitude
  - Test shearing forces on exterior mounted antenna
- Device constraints
  - Ensure device does not exceed User Guide defined weight or size limits
Electrical Testing

- Test power regulator
  - Ensure current does not exceed defined limits
  - Ensure device is providing accurate voltage levels to other subsystems
- INSS
  - Ensure INSS is providing accurate low and high G outputs
- Transistor Tester
  - Ensure transistors are functional
- Geiger
  - Ensure High Voltage circuit does not exceed defined limits
- SDR
  - Ensure sufficient power supplied to Pi while controlling SDR
Software Testing

INSS:

• I2C configuration in hardware needs to be set up before software can be tested.
• For hardware to be tested, needs completion of code that will record measurements from sensors and write to SD card.
• For test to be successful, test run must successfully display and write data to SD card for confirmation.
Software Testing

Transistor Tester:

- Software dependent on hardware for physical setup before testing
- To confirm transistor tester is successful, code that will test, measure, and record testing data on SD card must be completed
- Confirmation of success is if recorded data matches inspected measurements
Software Testing

SDR:
- Only hardware involved is Raspberry Pi Zero and antenna (along with transmitter for testing)
- To test hardware system, code to receive, process, and record signal data must be completed
System Level Testing

- Ensure canister mounts can withstand vibrational forces and hold PCBs in place
- Ensure INSS records real-time data to SD card
- Ensure Geiger records real-time data to SD card
- Ensure Transistor tester records real-time data to SD card
- All systems should run for 30 minute period
- Integrate all systems for flight simulation test
User Guide Compliance

Evan Somers

• The predicted mass is under 4 pounds.
• Predicted Volume
  – Diameter: 9.3 inches
  – Height: 4.75 inches
• We are requesting early activation in accordance with 1.SYS.1
• The Geiger counter and voltage upconverter will be conformal coated
• We are requesting exterior mount of one antenna from the port cover
Organizational Chart

Project lead
Avery Wimbrow

Faculty Advisor
Dr. Chase Cotton

Sponsor
Delaware Space Consortium

Software
Theodore Fessaras

SDR and Transistor
Azael Roa

Geiger
Evan Somers

SDR and INSS
Avery Wimbrow

Sponsor
Delaware Space Consortium
# Schedule: Fall (2019)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/28/19</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>TBD</td>
<td>Fall Midterm Report</td>
</tr>
<tr>
<td>12/4/19</td>
<td>Finish Schematics and Diagrams</td>
</tr>
<tr>
<td>TBD</td>
<td>Fall Presentation and Report</td>
</tr>
<tr>
<td>12/2/19</td>
<td>Critical Design Review</td>
</tr>
<tr>
<td>12/3/19</td>
<td>Begin building subsystems</td>
</tr>
<tr>
<td>TBD</td>
<td>Final Presentation and Report</td>
</tr>
<tr>
<td>1/20/20</td>
<td>Progress Update</td>
</tr>
<tr>
<td>2/20/20</td>
<td>Subsystem Testing Review</td>
</tr>
<tr>
<td>3/2/20</td>
<td>Progress Update</td>
</tr>
<tr>
<td>3/23/20</td>
<td>Integrated Subsystem Testing</td>
</tr>
<tr>
<td>4/27/20</td>
<td>Full Mission Simulation Test Report</td>
</tr>
<tr>
<td>6/1/20</td>
<td>Check in and Launch Readiness Due</td>
</tr>
<tr>
<td>6/17/20</td>
<td>Presentations to Future RockSAT</td>
</tr>
<tr>
<td>6/18/20</td>
<td>Launch Day</td>
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</tbody>
</table>
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Estimated, Specific Cost</th>
<th>Number Required</th>
<th>Total Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Axis Accelerometer</td>
<td>Sparkfun</td>
<td>$11.95</td>
<td>2</td>
<td>~$24.00</td>
<td>2 for data verification</td>
</tr>
<tr>
<td>Absolute Orientation Gyroscope</td>
<td>Adafruit</td>
<td>$33.59</td>
<td>2</td>
<td>$67.18</td>
<td>2 for data verification</td>
</tr>
<tr>
<td>Microcontroller (Teensy 4.0)</td>
<td>PJRC</td>
<td>$26.95</td>
<td>2</td>
<td>$33.80</td>
<td>2 for Accel/Gyro and Transistor</td>
</tr>
<tr>
<td>Raspberry Pi 4</td>
<td>RaspberryPi</td>
<td>$62.00</td>
<td>1</td>
<td>$62.00</td>
<td>For use with SDR</td>
</tr>
</tbody>
</table>

**Total (no margin):** $186.98

**Total (w/ margin):** $233.73
# Team Contact Matrix

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avery Wimbrow</td>
<td>Project Lead</td>
<td><a href="mailto:awimbrow@udel.edu">awimbrow@udel.edu</a></td>
</tr>
<tr>
<td>Azael Roa</td>
<td>Team Member</td>
<td><a href="mailto:aroa@udel.edu">aroa@udel.edu</a></td>
</tr>
<tr>
<td>Theodore Fessaras</td>
<td>Team Member</td>
<td><a href="mailto:tfessara@udel.edu">tfessara@udel.edu</a></td>
</tr>
<tr>
<td>Evan Somers</td>
<td>Team Member</td>
<td><a href="mailto:esomers@udel.edu">esomers@udel.edu</a></td>
</tr>
<tr>
<td>Dr. Chase Cotton</td>
<td>Faculty Supervisor</td>
<td><a href="mailto:ccotton@udel.edu">ccotton@udel.edu</a></td>
</tr>
</tbody>
</table>
# Team Availability

<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>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Conclusion

• Future Plans
  – Create 3D model of port designs
  – Begin investigating individual devices
  • Test INS
  • Begin development of transistor tester
  • Test for various RF signals and parameters with SDR
  – Collaborate with High school in partner experiment
The Delaware In Situ Probe
Critical Design Review
December 2, 2019

Team Members - Jarod Dagney, Kevin Flaherty, Richard Joyce, Jason Kalaygian, Pinar Selimoglu, Daniel Toy

Advisors: Ben Maruca (Faculty), Edward Graff (lab manager), and David Sundkvist (Consultant)
Mission Objectives

- Build a langmuir probe to measure the temperature and density of electrons in the lower ionosphere
- Create plots characterizing ionospheric plasma as a function of altitude in the D-layer during early morning ionization
Expected results

Figure: Electron temperature results plotted for the E-Region [5] Abe

Figure: Electron density plotted for nighttime and daytime launches [6] Barjatya

Figure: Sample I-V curve from the same study as the leftmost graph [5] Abe
## Comprehensive Success vs Minimum Success

<table>
<thead>
<tr>
<th>Mission Objective</th>
<th>Comprehensive Success</th>
<th>Minimum Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Robustness</td>
<td>Material coating on probe unaffected by vacuum</td>
<td>Minor hysteresis, probe remains intact</td>
</tr>
<tr>
<td>Voltage sweeps</td>
<td>10 &lt; freq</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Signal measurement</td>
<td>almost no noise, full I-V curves with saturated regions</td>
<td>Identifiable floating and plasma potentials</td>
</tr>
<tr>
<td>Sensor data</td>
<td>Gyroscope, accelerometer, magnetometer, and temperature sensor contextualize measurement</td>
<td>Gyroscope contextualizes measurement</td>
</tr>
<tr>
<td>Data Quantity</td>
<td>7 I-V curves per 2 km span</td>
<td>~ 100 I-V curves for analysis</td>
</tr>
</tbody>
</table>
# Functional and Design Requirements

<table>
<thead>
<tr>
<th>Functional Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical system resists drag forces</td>
<td>Test</td>
<td>The system will be constructed and have a similar force in weights hung from the probe to test mechanical robustness</td>
</tr>
<tr>
<td>Analog Device applies bias and reads in current data</td>
<td>Test</td>
<td>Analog circuit converts a current to a voltage, allows the Arduino to take appropriate measurements</td>
</tr>
<tr>
<td>Obtain contextual data for I-V curves</td>
<td>Test</td>
<td>Implement accelerometer, gyroscope, and magnetometer sensors</td>
</tr>
</tbody>
</table>
System Overview
2D PLATE DIAGRAM

- Radii measured by torque calculations
- Ballasts equidistant from each other

Battery: $M_B = 0.22$ lbs

PDU

Digital & Analog Stack: $M_S = 0.23$ lbs

$R_B = 0.15$ in

$R_S = 0.15$ in
SIDE DISPLAY OF THE HALF CANISTER

- BALLAST OMITTED

$R_B = 0.15 \text{ in}$

$R_S = 0.15 \text{ in}$

**Batteries**

**PDU**

**Digital & Analog Stack**

Plexiglass plate

8.5 in

Located at the center of mass of the canister
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>TOTAL MASS (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALOG</td>
<td>0.077</td>
</tr>
<tr>
<td>DIGITAL</td>
<td>0.162</td>
</tr>
<tr>
<td>BATTERY</td>
<td>0.22</td>
</tr>
<tr>
<td>PDU</td>
<td>0.2</td>
</tr>
<tr>
<td>PLATE (PLEXIGLASS)</td>
<td>0.455</td>
</tr>
<tr>
<td>STANDOFFS</td>
<td>0.25</td>
</tr>
<tr>
<td>Misc. (wiring, nylon cable ties, glue, etc)</td>
<td>0.25</td>
</tr>
<tr>
<td>BALLAST</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>6.00 lbs</strong></td>
</tr>
</tbody>
</table>
Multipurpose Port

- One SMA port requested to provide probe with direct access to plasma
- Requesting ~5” extension from rocket skin

Modified Cover with bevel and mounting holes
Subsystem Design

DIGITAL, ANALOG, POWER, MECHANICAL AND SOFTWARE
Subsystem Breakdown

- **DIGITAL**
  - Microcontroller, Sensors, SD Card, Flight Software

- **ANALOG**
  - Current to Voltage Converter, Sweep Circuit

- **POWER**
  - Batteries, Power Distribution Unit

- **MECHANICAL**
  - Probe Proper, (Rocket Interface)
Mechanical Probe Exploded Assembly

SMA Multipurpose Port
MPP Plate
Support Collar
Sapphire Spacer
Steel Rod
Aluminum Sphere
# Mechanical Mass Model

<table>
<thead>
<tr>
<th>Probe Component</th>
<th>Mass (lbm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPP Plate (aluminum)</td>
<td>0.19</td>
</tr>
<tr>
<td>Steel Rod (12L14 steel)</td>
<td>0.06</td>
</tr>
<tr>
<td>Spacer (sapphire)</td>
<td>0.05</td>
</tr>
<tr>
<td>Support Collar (aluminum)</td>
<td>0.29</td>
</tr>
<tr>
<td>Sphere (aluminum)</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.64</strong></td>
</tr>
</tbody>
</table>
### Mechanical Risk Matrix

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Possibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>High moment on MPP plate causes total failure</td>
<td>Green</td>
</tr>
<tr>
<td>Ceramic insert breaks</td>
<td>Yellow</td>
</tr>
<tr>
<td>Coating materials sloughs off</td>
<td>Red</td>
</tr>
</tbody>
</table>

- **Moment on MPP plate causes total failure**: If the drag force applies enough of a moment on the thin aluminum SMA port cover, the entire system will be compromised.

- **Ceramic insert breaks**: If the ceramic insert pokes out of the aluminum collar and experiences too much shear, it could break and we may lose electrical isolation.

- **Coating material sloughs off**: If the probe coating is lost due to drag, we will no longer have a uniform work function and may experience notable hysteresis.
Digital Subsystem

### Projected Weight:

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass (lbm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Due</td>
<td>0.077</td>
</tr>
<tr>
<td>SD Module</td>
<td>0.011</td>
</tr>
<tr>
<td>KX222 EVAL Board</td>
<td>0.013</td>
</tr>
<tr>
<td>SOIC-16 Breakout Board</td>
<td>0.0066</td>
</tr>
<tr>
<td>LSM9DS0</td>
<td>0.0066</td>
</tr>
<tr>
<td>TMP36</td>
<td>0.0022</td>
</tr>
<tr>
<td>PCB (estimate)</td>
<td>0.046</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.162</strong></td>
</tr>
</tbody>
</table>
Digital Schematic

- Arduino Due
  - 3.3V
  - 5V
  - DAC
  - ADC
  - ADC
  - ADC

- SD-Memory

- PDU
  - DC-DC Converter
  - 9V

- Analog Board

- Power
  - LSM9DS0
  - KX222-1054
  - TMP36
  - MMA-1210

- Data

Digital Risk Matrix

Digital Risk 1.
Cannot record I-V curves due to microcontroller capabilities i.e. overloaded processing

Digital Risk 2.
Cannot measure contextual data due to either sensor failure or arduino failure

Digital Risk 3.
Unable to decipher data from a corrupted file/packet
Analog Block Diagram

- **DAC**
- **Sweep Circuit**
- **Probe**

**Signal**
- **Arduino output voltage**
- **Power**

**Path to ADC**
- (Unity Gain Buffer, Voltage Divider, DC. Offset)

**Trans.-im p. Amp.**

**1st Gain Stage**

**2nd Gain Stage**

**3rd Gain Stage**
<table>
<thead>
<tr>
<th>Consequence</th>
<th>Analog Risk 1</th>
<th>Analog Risk 2</th>
<th>Analog Risk 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Possibility</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analog Risk 1.
Loose connections could compromise measurements

Analog Risk 2.
Resistors and other circuit elements should be chosen with a degree of caution, so that nothing gets damaged

Analog Risk 3.
Faulty connections could potentially damage the device, also compromising the experiment
Power Schematic
G-Switch activation

Figure 13: Activation Schematic with G-Switch Implementation (RockOn Workshop Design)
## Power Subsystem

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC DC Converter</td>
<td>0.010</td>
</tr>
<tr>
<td>DC DC Isolated</td>
<td>0.033</td>
</tr>
<tr>
<td>-12V Voltage Regulator</td>
<td>0.008</td>
</tr>
<tr>
<td>12V Voltage Regulator</td>
<td>0.008</td>
</tr>
<tr>
<td>Batteries (Not shown)</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.271</strong></td>
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</table>
## Power Budget

### The DIP - Power Budget

**12/2/2019**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Start Time (min)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino</td>
<td>9.0</td>
<td>0.10</td>
<td>0</td>
<td>15</td>
<td>0.90</td>
<td>0.03</td>
</tr>
<tr>
<td>PDU</td>
<td>15.0</td>
<td>0.03</td>
<td>0</td>
<td>15</td>
<td>0.45</td>
<td>0.01</td>
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<tr>
<td>Analog</td>
<td>12.0</td>
<td>0.05</td>
<td>0</td>
<td>15</td>
<td>0.60</td>
<td>0.01</td>
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</table>

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Start Time (min)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
<td>1.95</td>
<td>0.05</td>
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<tr>
<td><strong>Total Power Capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.70</td>
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<tr>
<td><strong>Over/Under</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.66</td>
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</tbody>
</table>

### # of Flights Margin

22.2
Prototyping and Analysis
## Probe Testing Methods

<table>
<thead>
<tr>
<th>Test</th>
<th>Explanation</th>
<th>Purpose</th>
<th>Expected Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag forces test</td>
<td>Hang weight off of probe to simulate drag forces during launch</td>
<td>Determine if design is suitable for resistance of expected drag forces</td>
<td>December, Sharp Laboratory</td>
</tr>
<tr>
<td>DAG conductivity test</td>
<td>Paint DAG on aluminum and test resistance using ohmmeter</td>
<td>Determine if DAG is conductive enough for the experiment</td>
<td>December, Sharp Laboratory</td>
</tr>
<tr>
<td>DAG air resistance test</td>
<td>Apply aquaDAG to piece of aluminum and simulate wind with air knife</td>
<td>Determine if DAG will be able to stay uniform on sphere during launch</td>
<td>February, Sharp Laboratory</td>
</tr>
</tbody>
</table>
## Mechanical Probe Manufacturing

<table>
<thead>
<tr>
<th>Part</th>
<th>Method of Acquisition</th>
<th>Date Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Sphere</td>
<td>Purchased (Salem Specialty Ball Co.)</td>
<td>In Possession</td>
</tr>
<tr>
<td>Steel Rod</td>
<td>Purchased (McMaster-Carr) and machined to specifications</td>
<td>12/7</td>
</tr>
<tr>
<td>Sapphire Tube</td>
<td>Custom-grown (COE Optics)</td>
<td>12/20</td>
</tr>
<tr>
<td>Alumina Tube (for misc. testing)</td>
<td>Purchased (McMaster-Carr)</td>
<td>12/7</td>
</tr>
<tr>
<td>Support Collar</td>
<td>Machined to specifications</td>
<td>12/2</td>
</tr>
<tr>
<td>MPP Port Cover</td>
<td>Delivered by Rocksat</td>
<td>April (custom copy by 12/2)</td>
</tr>
<tr>
<td>MPP Port</td>
<td>Delivered by Rocksat</td>
<td>April</td>
</tr>
</tbody>
</table>
Analog Testing Methods

- Inputting constant voltage and seeing if we can output a signal that is double the input via our circuit arrangement (by choosing two equal resistors)
Analog Testing Methods

- Using a function generator to simulate voltage sweeps and measuring the signal via an oscilloscope. Here we have included a voltage subtractor to eliminate voltage bias from the transimpedance amplifier.
Analog Prototype Schedule

**Testing Transimpedance Amplifier**
Using resistors in configurations that should theoretically output double the input voltage to the TIA

**Set up the first pathway to ADC**
Trying to measure an output voltage into the Due

**Sweep Circuit**
Output a sawtooth wave to the circuit, measure output of circuit rail to rail

**Completion of First Gain stage**
Measuring input voltages and amplifying them with gain factors that are proportional to feedback/input resistor ratios

**Integrate Sweep Circuit and Signal Circuit**
Apply voltage to a resistor using sweep circuit, measure current using signal circuit
Digital Prototype

- Provided 10 voltage sweeps, and polled start time and end time

```while
Loop Test
(milliSeconds)
Time,137,151
Time,38,52
Time,38,52
Time,38,53
Time,37,52
Time,38,52
Time,38,52
Time,38,52
Time,38,53
Time,37,52
Time,38,52
```

AVERAGE 14 ms to complete 2000 loops of 1 analogWrite and 3 digitalRead
Corresponds to 10 sweeps of 100 voltage steps.
Digital Prototype

- Functional Test with arduino reading three axis acceleration, three axis rotation, and three axis magnetic field from LSM9DS0 and writing it to a .csv file on SD card along with applying voltage sweeps. See appendix for code
Digital Prototype Results

- Able to produce 13 sweeps/sec reading in most of contextual data we will be using.
- Main source of concern is time to read from sensors
- Can ensure mission success by altering how often we are collecting certain sensor data
Software Flow Chart

Initialization:
- Open communication with sensors
- Open file on SD Card

Loop: Voltage Sweep, Read Sensors, Write to Storage

- Apply voltage sweep up
- Read voltage in
- Store in Voltage Packet

- Read data from some sensors
- Store in Sensor Packet

- Apply voltage sweep down
- Read voltage in
- Store in Voltage Packet

- Read data from rest of sensors
- Store in Sensor2 Packet

Write Packets to SD Card
Software Development/Digital Board

Access to past successful flight software of TILDAE High Altitude Balloon Mission via Bennett Maruca and David Sundkvist

Main blocks of code include voltage sweep, sensor reading, and memory writing

Power-Analog-Digital Test will need voltage sweep code to validate integration

Sensor PCB design will begin after Winter Break
Digital Testing Methods

| Test                                      | Explanation                                           | Purpose                                                        |
|-------------------------------------------|-------------------------------------------------------|                                                               |
| Microcontroller-Sensor Connection         | Individually connect and read data from each sensor   | Ensure correct functionality with Arduino Due                  |
| Microcontroller-Sensor Connection +       | Connect and read data from every sensor concurrently  | Ensure collection of data is viable                             |
| Complete Mission                          | Apply voltage sweep and read data from all sensors concurrently | Ensure mission success of at least 10 sweeps/second with contextual data |
Digital Testing Schedule

- **Nov/Dec**: Preliminary Sensor Tests
  - Microcontroller-Sensor Connections

- **Jan**: Complete Sensor Tests
  - Microcontroller-Sensor Connections + Begin PCB design for digital board

- **Feb**: Power-Analog-Digital Integration
  - Simulate current from probe to analog system at UD

- **March**: Flight and Ground Software Integration
  - Create software to analyze packets from SD card

- **April/May**: Finalization of Flight Software
  - Complete mission test in plasma chamber at Swarthmore College
<table>
<thead>
<tr>
<th>Systems</th>
<th>Test Name</th>
<th>Test Description</th>
<th>Date</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power &amp; Analog Analog</td>
<td>SweepTest</td>
<td>Power system is used by the analog system to apply voltage/measure current (benchtop)</td>
<td>Early February</td>
<td>Sharp Lab, University of Delaware</td>
</tr>
<tr>
<td>Power, Analog and Digital</td>
<td>Electronics integration</td>
<td>Full electronic integration, circuit based simulation generates data to be read in on an SD card (benchtop)</td>
<td>Early March</td>
<td>Sharp Lab, University of Delaware</td>
</tr>
<tr>
<td>Mechanical and Electronics</td>
<td>Full integration</td>
<td>Circuit element used for electronics test is replaced with the probe. Same results as Electronics integration (PCB &amp; Full probe)</td>
<td>Early April</td>
<td>Sharp Lab, University of Delaware</td>
</tr>
<tr>
<td>Full Suite (Partial Ground software included)</td>
<td>Plasma Chamber Test</td>
<td>Obtain data in a plasma chamber, generate IV curves and produce sample calculations on data</td>
<td>May</td>
<td>Swarthmore College</td>
</tr>
</tbody>
</table>
## Descopes

<table>
<thead>
<tr>
<th>Problem</th>
<th>Descope</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino processing for the SD card is too slow</td>
<td>Lower the number of steps</td>
<td>Less data per sweep</td>
</tr>
<tr>
<td>Power source is limited</td>
<td>Lower sweep range</td>
<td>Plasma parameters are out of scope</td>
</tr>
<tr>
<td>DAG coating is not conductive and/or is not strong enough</td>
<td>Go without coating</td>
<td>Deal with hysteresis in the curve caused by contamination of surface</td>
</tr>
</tbody>
</table>
# RockSat-C 2020 User’s Guide Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity</td>
<td>Within 1&quot; centered ensured by PDU</td>
</tr>
<tr>
<td>Mass (half canister~10lbs)</td>
<td>Currently ~ 6 lbs</td>
</tr>
<tr>
<td>Grounding</td>
<td>Grounding to multipurpose port (request submitted)</td>
</tr>
<tr>
<td>Activation</td>
<td>G-switch activation</td>
</tr>
<tr>
<td>Battery Type</td>
<td>2 Lithium-ion batteries combined ~ 18.2V</td>
</tr>
<tr>
<td>Special request</td>
<td>Protrusion from rocket body using a multipurpose port (request submitted)</td>
</tr>
</tbody>
</table>
Group Organization

- **Project manager:** Jason Kalaygian
- **Secondary:** Mechanical
- **Analog System:** Daniel Toy
- **Secondary:** Systems Engineer
- **Power Engineer:** Kevin Flaherty
- **Secondary:** Analog

- **Systems Engineer:** Jarod Dagney
- **Secondary:** Software

- **Software/Data:** Pinar Selimoglu
- **Secondary:** Safety

- **Mechanical Engineer:** Richard Joyce
- **Secondary:** Power

**Mentors:**
- Faculty: Ben Maruca
- Lab manager: Edward Graff
- Langmuir expert: David Sundkvist
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Estimated Cost</th>
<th>Number Required</th>
<th>Total Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSM9DS0 (2 in stock)</td>
<td>Adafruit</td>
<td>$14.95</td>
<td>0</td>
<td>$0.00</td>
<td>Low Range Accel</td>
</tr>
<tr>
<td>KX222-1054 EVB0A0</td>
<td>DigiKey</td>
<td>$13.30</td>
<td>3</td>
<td>$39.90</td>
<td>Med Range Accel</td>
</tr>
<tr>
<td>MMA1210KEG</td>
<td>NXP SemiCond</td>
<td>$3.50</td>
<td>3</td>
<td>$10.50</td>
<td>High Range Accel</td>
</tr>
<tr>
<td>Arduino Due</td>
<td>Adafruit</td>
<td>$38.50</td>
<td>2</td>
<td>$77.00</td>
<td>Microcontroller</td>
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<td>Agar Scientific</td>
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<td>Aerocon</td>
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<td>mini-timer</td>
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|                                |                          |                |                | Total Cost: $594.00  |
|                                |                          |                |                | 25% Margin: $742.50  |
## Contact Matrix

<table>
<thead>
<tr>
<th>Team member</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jason Kalaygian</td>
<td><a href="mailto:jaykalay@udel.edu">jaykalay@udel.edu</a></td>
<td>(302)-531-6128</td>
<td>Y</td>
</tr>
<tr>
<td>Jarod Dagney</td>
<td><a href="mailto:jwdagney@udel.edu">jwdagney@udel.edu</a></td>
<td>(717)-517-2560</td>
<td>Y</td>
</tr>
<tr>
<td>Kevin Flaherty</td>
<td><a href="mailto:kflah@udel.edu">kflah@udel.edu</a></td>
<td>(412)-508-3505</td>
<td>Y</td>
</tr>
<tr>
<td>Pinar Selimoglu</td>
<td><a href="mailto:pinarsel@udel.edu">pinarsel@udel.edu</a></td>
<td>(302)-367-4121</td>
<td>Y – Resident alien</td>
</tr>
<tr>
<td>Richard Joyce</td>
<td><a href="mailto:rmjoyce@udel.edu">rmjoyce@udel.edu</a></td>
<td>(631)-792-2513</td>
<td>Y</td>
</tr>
<tr>
<td>Dan Toy</td>
<td><a href="mailto:dannyt@udel.edu">dannyt@udel.edu</a></td>
<td>(302)-528-4180</td>
<td>Y</td>
</tr>
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Availability Matrix

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<tr>
<th>Team Name/School Here: DPA Langmuir Probe</th>
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<td></td>
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</tr>
</tbody>
</table>

PLEASE USE MOUNTAIN TIME ZONE TIMES

Key: Yes, available | No, unavailable

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Appendix

Concept of Operations

Example Code

Mechanical Drawings etc.
Code: Voltage Sweep with Sensor Data

File has columns corresponding to:
time,vOut,xAcc,yAcc,zAcc,xGyro,yGyro,zGyro,xMag,yMag,zMag

For loop applies voltage sweep up, reads 3 digital pins, and records value of vOut w/out data for sensors. *Future test will include writing digitalRead value to SD as well. After sweep up, write to SD acceleration data, rotation data, magnetic field data.

Similar for loop for the voltage sweep down, as well as sensor reading out of for loop
Rocket Trajectory

![Rocket Trajectory Diagram]

- Apogee ~ 115 km
- E-Region
- D-Region
- 25 km Probe Sweep
- 90 km
- Chute Deploy
- Shut off Stop data ~ 10 min

**T = 0 min**
G-switch activation
Start Data

**Time**

~5.5 min