Mission Overview
Ronald Willis
Mission Overview (Updated)

• Mission statement
  – The goal of PiGen2 is to successfully record an accurate vibration profile of the rocket in order to construct a Power Spectral Density report.
  – No special ports are needed.
  – This report will be provided to NASA and future Rock On, RockSat c/x, and CubeSat teams for payload design analysis.
  – The importance behind this research lies in the very nature of experiments onboard a rocket. The harmonic frequency of a mechanical system should never match the driving frequency. When this occurs in a mechanical system catastrophic damage can be the result.
  – We expect to finding a large variation in frequency with some hertz consistency.
Mission Overview: Mission Objectives

• Mission Objective:
• Our only mission objective is to monitor the oscillation of the moving sounding rocket on the X, Y and Z plane in order to generate a vibration profile of the rocket.
• The equation for simple harmonic motion is:

\[ x(t) = A \sin(2\pi ft + \phi) \]

• This equation continues in complexity to add velocity and then acceleration at any time.
• Last year our team constructed an experiment that also used this type of Piezo technology.
ConOps

Altitude

Hertz range shrinks
\[ t \approx 1.3 \text{ min} \]
Altitude: 75 km

Initial and second burn.
Strongest hertz expected to be seen in this range

End of Orion Burn –
Spin Rate Largest,
Hertz range begins
To taper after this point
\[ t \approx 0.6 \text{ min} \]
Altitude: 52 km

- Power engaged upon NASA power up
- All systems on
- Begin data collection
- Accelerometer and Gyroscope will send data until power is turned off.

Ambient Hertz of rocket at apogee
\[ t \approx 2.8 \text{ min} \]
Altitude: \( \approx 115 \text{ km} \)

High Tumble Rate
New hertz range
\[ t \approx 4.0 \text{ min} \]
Altitude: 95 km

Natural hertz range of rocket (open or closed) without engine interference
\[ t \approx 5.5 \text{ min} \]
Chute Deploys

- Splash Down
- End data collection

Chute Deploys

Hertz range begins to taper after this point

\[ t \approx 0.6 \text{ min} \]
Altitude: 52 km
Expected Results (Updated)

• We expect to see a large hertz range with periods of nearly steady hertz during a burn.

• We expect to see hertz ranges change as the atmosphere thins and then thickens on return.

• We also expect to see hertz ranges jump and fall sharply during a burn start and end.
• Minimum Success Criteria:
  – Retrieving usable data on one axis.

• Comprehensive Success Criteria:
  – Retrieving usable data on all three axes and retrieving gyroscopic and acceleration data.
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PiGen shall record vibration data for the rocket from within the canister</td>
<td><strong>Demonstration</strong></td>
<td>Vibration tests will confirm the Piezo ceramic discs are being recorded accurately, i.e. washing machine and desk fan tests.</td>
</tr>
<tr>
<td>PiGen shall record acceleration and orientation data for the entire launch</td>
<td><strong>Demonstration</strong></td>
<td>• An ADIS Gyroscope/Accelerometer will be powered for the entire flight. This ADIS device will be powered on for an hour to make sure the device will continuously record relevant data.</td>
</tr>
<tr>
<td>PiGen shall not generate signal interference</td>
<td><strong>Inspection</strong></td>
<td>• All traces will be straight lines or at a 45/90 degree angle from emitter to receptor. No loop shaped traces shall be placed. Inspection of traces will prove this. Testing for voltage spikes will commence upon receipt of the Ceramic Tabs.</td>
</tr>
</tbody>
</table>
System Overview
Ronald Willis
System Definitions

• Our system this year has been streamlined for simplicity and convenience:
• 1 Raspberry Pi 3B
• 3 Piezoelectric Ceramic Discs
• 1 Yeeco boost/buck circuit with 40v range
• 1 ADC (Analog to Digital Converter)
• 1 ADIS (Analog Devices) Gyroscope/Accelerometer
Changes Since PDR

• No major/minor design changes have occurred since PDR.
System Level Block Diagram

- Show a full system of your subsystems, and the connections between them

Legend:

- Data/Control
- High Voltage
- Low Voltage

Components:
- Raspberry Pi
- Memory Card
- ADIS 6 DOF Gyrocope
- Yeeco Boost Circuit
- ADC
- Power
- RBF (Wallops)
- Piezo 1
- Piezo 2
- Piezo 3
The Inventor model needs a bit of touch up work on the PCB, but this is very close to the final layout.
System Design – Physical Model

BRCTC-2017
Electrical Design Elements

Legend

- **Data/Control**
- **High Voltage**
- **Low Voltage**

- Power
- Raspberry Pi
- Yeeco Boost Circuit
- Memory Card
- ADIS 6 DOF Gyroscope
- ADC
- Piezo 1
- Piezo 2
- Piezo 3
- RBF (Wallops)
Electrical Design Elements

- No changes since PDR
Software Design Elements

- The main functions of our code are input voltage sampling, reading and appending data.
- The code will end 30 minutes after it begins.
- The pi will reset itself and begin running the code, if an error occurs.
```c
int main()
{
    int rc = Startup();
    if (rc != 0) {/*Restart Pi if Startup fails*/}
    else if (rc == 0)
    {
        //printf("Program is running.");
        string fileName = "Data.txt"; // file name, to be passed as an argument
        for (int i = 0; i<3; i++) // set pins to output
        {
            pinMode(selectPins[i], OUTPUT);
            digitalWrite(selectPins[i], HIGH);
        }
        for (uint8_t i = 0; i < 4; i++) { //Loop through ADC inputs
            pinMode(i, INPUT);
        }
        WriteHeader(fileName);
        while (true) //Change to Start Time + 30
        {
            for (uint8_t pin = 0; i = 0; pin <= 5; pin++, i++) // instead of
            { // instead of
                selectMuxPin(pin); // Select one at a time
                double inputValue = analogRead(i); // and read Z
                inputValue *= (4.096 / 32768);
                WriteData(fileName, inputValue, pin);
            }
        }
    }
    return 0;
}
```
Read RTC and use data to append date to filename

Sample hardware reference voltage. Modify software reference voltage from sample

Create current time variable. Create a loop control variable (+30 minutes from current time)

Generate headers in file

Current Time < End Time?

Data Threads

Yes

No

Stop

GetData()

Piezo/ADC Thread

Stop

Gyro Thread
De-Scopes and Off-Ramps

- Nothing with the experiment has changed.
- If we have troubles with the new Piezo discs, we can switch them out for the tabs we used last year.
- If we have troubles with the new Gyro, we can switch it out for the older model we used last year.
Subsystem Design
Ronald Willis

Raspberry Pi 3 B
Block Diagram: 16 Bit ADC

- The Raspberry Pi 3 B was a challenge to start working with, but we like this tiny computer and could find no other replacement for the same low price and power that it provides.
Trade Studies: Microcontroller

- The Raspberry Pi 3B offers more features than the Arduino platform. RP 3B is also faster and more precise. We need the extra performance boost.

<table>
<thead>
<tr>
<th>µController</th>
<th>Arduino Platform</th>
<th>Raspberry Pi 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Size</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Performance</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Versatility</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Heritage</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Average:</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

- The Raspberry Pi is less expensive when all subsidiary devices needed for a complete system are added to the cost.

- Both micro-controllers fit our size needs, but the performance of the Raspberry Pi far outweighs Arduino.

- HDMI connection allows programmers to easily change code without complication.
Subsystem Design
Ronald Willis

Piezoelectric Ceramic Discs
3 Piezoelectric actuating transducers connect to an ADC to sum up the voltage in order to see the voltage range, which in turn allows us to calculate the hertz range at any given moment. We used Piezo cantilever wafer tabs last year, but these were ultimately too delicate, so we decided to use discs for the increased hertz resistance. We are currently researching the changes needed to integrate the new parts.
Trade Studies: Piezo Element

- Piezoelectric Ceramic discs are much hardier than the cantilever wafer tabs, so the use of these will greatly increase the odds of mission success.

<table>
<thead>
<tr>
<th>µController</th>
<th>Wafer</th>
<th>Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Size</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Performance</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Versatility</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Heritage</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

- Ceramic discs are smaller and easy to mount.
- Wafers need to much space to deflect.

Average: 7.6 8.2
Subsystem Design
Ronald Willis

Yeeco 2577 DC DC Boost Converter
Block Diagram: Yeeco 2577 DC DC Boost Converter

- If not for the mistake made last year with not plugging in the secondary battery, this boost/buck circuit would have allowed up to be powered with no damage to the experiment. Yet again another part that fits our experiment quite well.
Subsystem Design
Ronald Willis

ADIS Gyroscope and Accelerometer
This new model of the ADIS16460 is more resilient and contains an Accelerometer built in, reducing the space needed for components on the board and simplifying our code.

The last model worked very well, so we are confident the new model will be a satisfying improvement.
Subsystem Design
Ronald Willis

16 Bit ADC
We used this device last year and were highly satisfied with the performance we saw. There is no need to change out this part. We have the code for it and there are no cheaper parts with the same specs that we could find.
Trade Studies: ADC and ADIS Gyro

- The ADIS gyroscope/accelerometer was given to use as parts to try and have worked wonderfully. We looked into other parts, but these two are perfect for our purposes. There was no need to look for other variations past a quick search for price differences. These are the two best pieces of technology we could find that fit our purposes without going overboard and in the high price range.

- The Yeeco Boost circuit is cheap, sturdy, and again a part we could not find a cheaper price for when ranking reliability against other contenders.
- With HDMI off, LEDs off, and onboard WiFi off the Voltage required is 5V with 250 mA current draw.
- Direct connection into PCB
- 42 grams
- Data: coded in C++
- Final
Subsystem Design – Yeeco Boost Circuit

- Converts from .5V up to 25V
- First connection after the power connector
- 8.5 grams
- Data: None
- Final
Subsystem Design – ADIS Gyroscope

- Model currently being updated
- 3.15V with a 44 mA current draw
- Connects to Raspberry Pi
- Data: SPI
- 15 grams
- Final
Subsystem Design – Adafruit ADC

- 3.5V at 15 micro Amp current draw
- Converts physical hertz into a digital signal for the Raspberry pi.
- 8 grams
- Data: I2C
- Final
Subsystem Design – Piezo Discs

- Produces 0-10V analog signals
- Connects to the ADC
- 7 grams
- Data: none
- Final
RSK.1: Mission failure from the Piezo ceramic tabs failing or by Producing voltage spikes, which means any issue will delay completion of prototyping and final PCB integration.

We have already begun researching to mitigate this risk. All other systems were tested successfully last year.
EPS: Risk Matrix

- **R2** - Piezoelectric Generator breakdown
  - Destruction of generator due to excessive vibration would mean mission failure.
  - The resonant frequency of the new Piezo Disc Crystals is 18,000 hertz, which is well above the expected and previously seen vibration range.

- **R3** - Overheating
  - Excessive heat could cause component failure and cause mission failure.
  - For the past 2 years temperature has not been an issue, but we are still using our ABS case for general protection against physical and environment damage.

- **R3** - Coding Errors
  - Human error or software problems could cause anywhere from a slight issue to mission failure.
  - Practice! Walter has a great deal of practice at this point and we even have a new programmer this year to help him make sure all code is working properly.

- **R5** - Sensor Failure
  - Failure of sensor due to excessive G-Forces could cause us to lose our gyro and acceleration data. While this is not mission critical and can be retrieved from other teams, it is preferred that our experiment is self sufficient.
  - We did not receive power last year, but we tested our systems after and there was no damaged caused by g forces.
Subsystem Design – Weight Budget

- Present your subsystem weight and total weight similar to what is given at the right.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry Pi 3 B</td>
<td>0.0925942</td>
</tr>
<tr>
<td>Yeeco Boost Circuit</td>
<td>0.0187393</td>
</tr>
<tr>
<td>ADIS Gyrocope</td>
<td>0.0330693</td>
</tr>
<tr>
<td>Adafruit ADC</td>
<td>0.017637</td>
</tr>
<tr>
<td>Piezo Disc X 3</td>
<td>0.0462971</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Total (lbs)</td>
<td>0.2083368</td>
</tr>
<tr>
<td>Over/Under</td>
<td>(19.7916632)</td>
</tr>
</tbody>
</table>
## Subsystem Design – 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>Raspberry pi 3</td>
<td>5</td>
<td>.250</td>
<td>15</td>
<td>1.25</td>
<td>0.00</td>
</tr>
<tr>
<td>ADIS Gyroscope</td>
<td>3.15</td>
<td>.044</td>
<td>15</td>
<td>.139</td>
<td>0.00</td>
</tr>
<tr>
<td>Adafruit ADC</td>
<td>3.5</td>
<td>.0000015</td>
<td>15</td>
<td>.00000525</td>
<td>0.00</td>
</tr>
<tr>
<td>Piezo discs</td>
<td>Variable</td>
<td>Variable</td>
<td>Variable</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.00</strong></td>
<td></td>
<td><strong>1.38900525</strong></td>
<td><strong>0.07350038</strong></td>
<td><strong>0.00</strong></td>
</tr>
</tbody>
</table>

**Total Power Capacity**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Over (+)/Under (-)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
</tbody>
</table>

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Prototyping & Analysis
Ronald Willis
Analysis Results/Plans

• What was analyzed/tested since PDR?
  – Parts came in over the past week. We have not been able to prototype the entire system yet. We are waiting on the last part.
  – We have plans to set up a dc motor and have a weight placed on one side to produce oscillations.

• What are the key results expected?
• We expect to see a fairly consistent voltage spike pattern.

• How do these results relate to the project requirements?
• Reliability and accuracy of measuring voltage spikes makes the difference between mission success and failure.
Manufacturing Plan
Ronald Willis
Mechanical Elements

- A new case and updated PCB needs to be fabricated.

- The Yeeco Boost Board has not arrived yet.

- The PCB is currently being created via Advanced Circuits’ software and should be ready a week after finals are finished.
Electrical Elements

• Pins need to be soldered to the Yeeco and Adafruit ADC and all pins must be soldered to the PCB.

• We anticipate 0-1 revisions for electronics due to the simplistic design of the experiment.

• Yeeco Boost Board.

• After receipt of the PCB we should have soldering finished within a week.
Software Elements

• The gyroscope code needs to be modified to support the replacement.
• The multiplexer has been removed, so instead of one ADC pin, there is now four.
• The accelerometer has been removed from the payload, and so does the code for it.
• The headers in the master file must be modified to support these changes.
• It will take approximately two weeks to modify the code.
Testing Plan
Ronald Willis
Mechanical Testing

• Vibration testing is the only form of analysis needed. All parts were tested last year for functionality.

• A start up and system test will be performed to verify the new parts work as intended compared to the previous years’ counterparts.

• Start up
• General system test
• Vibration tests

• These tests will be performed on breadboard next week and on the PCB after fabrication.
Electrical Testing

• With the exception of the parts being newly ordered, we know the parts (if not containing defects) work as compared to last year.
• All parts will be connected to the Raspberry Pi to see if each is working as expected.

• Tests will be performed next week for components that have software code finalized.

• The only possible higher voltage components are the Piezo discs. The discs will be tested for dangerous spikes.
Software Testing

- Starting next week Software code will be developed and full system testing will begin in January.
The system needs to be able to hold up to 2000 physical hertz (all components except for the new ADIS Gyro has been tested previously) and be able to measure the change oscillation amplitude and frequency.

We will be measuring Physical hertz through a multitude of different tests.

Tests will be performed continuously starting next week after code is finished for each component.

Tests will be performed at my home or the college Mechatronics lab with Advisor permission.

We will need vibration sources and I will be overseeing all testing.
Project Summary

• The only issue we have is testing the piezo discs for proper usage. Nothing like this is filmed on youtube (that I could find), so this application is new for these components.
Worries

- Our only worry is making sure we are receiving the correct data from the Piezo discs.
• Now that we have all parts, we are going to prototype our design and stress test the new piezo discs. All other parts will be tested for functionality and final arrangement on the PCB will be assessed and finalized.
Space Flight Design Challenge Critical Design Review

Fairmont State University
Tyler McGee, Trinité Klamadji, Carlos Alexander
12/7/2018
CDR Presentation Content

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

• **Section 2: System Overview**
  – Block Diagrams
  – Mechanical Design Elements
  – Electrical Design Elements
  – Software Design Elements
  – Detailed Mass Budget
  – Detailed Power Budget
• Section 3: Manufacturing Plan
  – Mechanical Elements
  – Electrical Elements
  – Software Elements
• Section 4: Testing Plan
  – System Level Testing
    • Requirements to be verified
  – Mechanical Elements
    • Requirements to be verified
  – Electrical Elements
    • Requirements to be verified
  – Software Elements
    • Requirements to be verified
Mission Overview

Tyler McGee, Carlos Alexander, Trinité Klamadji
Mission Overview (Updated)

- **Mission statement**
  - The goal of Lego Space is to profile the temperature variations of the atmosphere and evaluate the reliability of Lego technology in space

- **Break mission statement down into your overall mission requirements**
  - Our mission requirements include the capacity for our payload to last into space and efficiently record temperature variations

- **What do you expect to discover or prove?**
  - That Lego technology can be flown into space and used to record temperature measurements
  - A durable lightweight solution exists to record temperature variations in the atmosphere in alternative to the current methods being used.

- **Who will this benefit/what will your data be used for?**
  - This would benefit Fairmont State University’s Information Systems department and everyone involved in this project
  - This project would also benefit the Lego community because Lego robotics in space will be a first in history.
  - Our data can be used for knowledge furthering on temperature variations within the atmosphere
Mission Overview: Mission Objectives

- Mission Objectives → derived from mission statement
  - Objectives:
    - Acquire temperature readings from launch pad up through atmosphere into space
    - Operationally test and evaluate the reliability of Lego technology
Mission Overview: Expected Results

- **Temperature Measurements**
  - Expectation is that with an increasing altitude we expect to see a decrease in temperatures up through the Troposphere.
  - Expect to see temperatures increasing (relative to Troposphere) as the payload begins flying through Stratosphere.
  - Expect to see temperatures begin decreasing again as the payload begins flying through Mesosphere at altitudes of 50 KM to 80 KM.
  - Expect to see temperatures begin increasing (relative to Mesosphere) while payload enters and flies through Thermosphere.
Theory and Concepts (Updated)

• Temperature
  • Earth’s atmosphere can be divided into four layers with distinct changes in temperature as the altitude increases
    • Troposphere (0 – 10 Kilometers (KM))
      • As altitude increases the air temperature decreases
      • Heat from the Earth warms this layer and as altitude increases the number of air molecules decreases. This results in a decrease in air temperature with an increase in altitude
    • Stratosphere (10 – 50 KM)
      • As altitude increases the air temperature increases
      • The Stratosphere has a layer of ozone, called the ozone layer. This layer absorbs most of the ultraviolet radiation from sunlight. This results in stratosphere being warmer
    • Mesosphere (50 – 80 KM)
      • As altitude increases, the air temperature decreases
      • The Mesosphere experiences a decrease in the density of air molecules hence the air temperature decreases as well
    • Thermosphere (80 – 200 KM)
      • As altitude increases the air temperature increases
      • The Thermosphere is warmed by absorption of solar X-Rays by the Nitrogen and oxygen molecules
  • What other research has been performed in the past?
    – Temperature measurements of the atmosphere have been recorded numerous times and continue to be recorded.
    – Temperature measurements using Lego technology has never been recorded nor has Lego technology (Lego robotics) been flown into space
Concept of Operations *(Updated)*

- Based on science objectives, diagram of what the payload will be doing during flight, highlights areas of interest
- If you’re looking at certain parts of the atmosphere mark the time
- If you are waiting for particular events in flight, mark those on the diagram with a time (approximate)
- Show a parallel flow from the point of view of your payload, noting what events will occur when, any moving parts or changing states

- *Example on following slide*
ConOps

- G switch trigger
- All systems power on
- Begin data collection

Lowest Thermosphere Temperatures (-60 C)
Altitude: 0 - 10 km

Apogee & Thermosphere increasing temps (-60 C)
Altitude: ≈115 km

Decrease Temperatures Mesosphere (-80 C)
Altitude: 50 - 80 km

Rising Temperatures Stratosphere (0 C)
Altitude: 10 - 50 km

High Tumble Rate
t ≈ 4.0 min
Altitude: 95 km

Chute Deployment
t ≈ 5.5 min

Splash Down
t ≈ 15 min
Success Criteria (Updated)

- Minimum Success Criteria:
  - Recovery of 25% data expected
  - Lego’s if broken do not leave the protective barrier created

- Comprehensive Success Criteria:
  - 85% data recovery of data expected
  - Lego design remains intact and in place
  - Minor damage to Lego shell
  - Successfully be the first to do something in space
Functional & Design Requirement Guidelines

**System Requirements**

- System shall acquire temperature readings every 500 feet in altitude change

- System shall measure reliability, response time, and data throughput of Lego technology during operations

- System shall provide its own memory storage

- System shall safely interface with Canister interface for power

- Shall provide its own structures and be less than or equal to 4 inches by 4 inches by 1.25 inches and weigh less than 2 pounds
System Requirements

- System shall acquire temperature readings every 500 feet in altitude change
- System shall measure reliability, response time, and data throughput of Lego technology during operations
- System shall provide its own memory storage
- System shall safely interface with Canister interface for power
- Shall provide its own structures and be less than or equal to 4 inches by 4 inches by 1.25 inches and weigh less than 2 pounds
**Example** Functional Requirements: **Updated**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System shall acquire temperature readings every 500 feet in altitude change</td>
<td><strong>Demonstration</strong></td>
<td>The system will use a thermometer and altimeter to read and log temperatures every time the altitude changes by 500 feet</td>
</tr>
<tr>
<td>System shall measure reliability, response time, and data throughput of Lego technology during operations</td>
<td><strong>Demonstration</strong></td>
<td>System will measure how well the Lego technology operates as well as record its output</td>
</tr>
<tr>
<td>System shall provide its own memory storage</td>
<td><strong>Inspection</strong></td>
<td>System will have its own onboard memory in order to store logs and other necessary data</td>
</tr>
<tr>
<td>System shall safely interface with Canister interface for power</td>
<td><strong>Test</strong></td>
<td>System will communicate with the canister in order to use its own source of power</td>
</tr>
<tr>
<td>Shall provide its own structures and be less than or equal to 4 inches by 4 inches by 1.25 inches and weigh less than 2 pounds</td>
<td><strong>Inspection</strong></td>
<td>System shall be measured and put on a scale</td>
</tr>
</tbody>
</table>
System Overview

Tyler McGee, Carlos Alexander, Trinité Klamadji
System Level Block Diagram

- Power Supply
  - Supplies power to whole operation
- Memory
  - Supplies memory to computer
- Computer
  - Requires sensor readings and temperature data
  - Passes data to computer
- Temp Sensor
  - Passes data to computer
- Barometric/Altitude Sensor
  - Passes data to computer
- Gravity Switch
  - Terminates computer during IR off

All components will be encased within a Lego Casing or will be Lego components.
Mechanical Design Elements

Was anything not modeled?

• Everything will be modeled in the next slide, however, most of it will be encased within Lego’s.

How do you know this design will survive flight?

• Sending Lego’s or Lego technology into space has not yet been done so we plan on being the first. With looking at the specifications we expect a mission success.
System Design – Physical Model

- **Battery pack** from Lego NXT computer
  - Supplies power to whole operation

- **Lego USB** to provide external memory to Lego NXT computer
  - Supplies memory to computer

- **Inner workings of the Lego NXT** computer that will be used
  - Gives sensor readings to memory
  - Gives temperature reading to computer

- **Lego Thermometer** to measure atmospheric temperatures throughout mission

- **Lego Barometer** to be used to gather altitude readings

- **Arduino Accelerometer**
  - To act as a gravity switch
  - Turns on computer during lift off

- **Example of Lego Casing**
  - All components will be encased with a Lego Casing or will be Lego components.
The NXT Brick will be the computer used to control all functions throughout the flight. This system just like all the other sensors that will be listed will all be fully integrated because they are all a part of the same brand. This product has not been tested for space but will be powered by it’s recommended power source of six AA batteries.
The Arduino accelerometer will act as a gravity switch to turn on the system when the rocket starts to take off.

This system will act as a mid point between the batteries and the actual NXT brick as shown in the previous diagrams.
Electrical Design Elements- Battery Pack

- This will act as the power supply throughout the whole mission.
- This will interact with the Arduino accelerometer to determine when to start outputting the energy to the rest of the system.
Electrical Design Elements- USB

- The NXT Brick does not have any internal memory so as outlined in the diagrams this USB stick will operate as external memory to record all data that is to be collected.
Electrical Design Elements- Lego Mindstorms Temperature Sensor

- This sensor will relay directly with the NXT Brick to provide temperature readings throughout the mission.
- The readings then will go into the external Memory device for data collection.
Electrical Design Elements - Lego NXT Barometer

- This sensor will relay directly with the NXT Brick to provide barometric readings to gather the data needed to consider mission success.
Software Design Elements

• All software being used is proprietary through Lego Technology.

• Most of the work is already completed for this project it just hasn’t been used in a setting like this before.

• Only programming necessary may be some minor compatibility coding with Arduino
<table>
<thead>
<tr>
<th>Consequence</th>
<th>Risk.1</th>
<th>Risk.4</th>
<th>Risk.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk.13</td>
<td></td>
<td>Risk.11</td>
<td></td>
</tr>
<tr>
<td>Risk.19</td>
<td>Risk.12</td>
<td></td>
<td>Risk.9</td>
</tr>
<tr>
<td>Risk.13</td>
<td></td>
<td>Risk.14</td>
<td></td>
</tr>
<tr>
<td>Risk.19</td>
<td>Risk.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk.2</td>
<td></td>
<td>Risk.6</td>
<td></td>
</tr>
<tr>
<td>Risk.15</td>
<td>Risk.8</td>
<td></td>
<td>Risk.17</td>
</tr>
<tr>
<td>Risk.10</td>
<td>Risk.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk.10</td>
<td></td>
<td>Risk.16</td>
<td></td>
</tr>
<tr>
<td>Risk.10</td>
<td></td>
<td></td>
<td>Risk.20</td>
</tr>
</tbody>
</table>
Risks

• 1 = Rocket blowing up
  – Not probable but just in case we know what will happen. Very low probability of occurrence.

• 2 = Acquisition of product
  – Some products may take too long to ship depending on destination. will cause few disruptions.

• 3 = Arduino not compatible
  – The only non Lego piece being used may not work with the NXT Brick to power on the device at liftoff.

• 4 = Glue does not hold up
  – The glue most Lego modelling uses may not hold up in space like weather.

• 5 = Temperature probe exceeds limit
  – Temperature probe being used was not made to track the temperature we are seeking to record.
Risks

• 6 = Soldering of equipment damages it
  – Some items may need soldered to stay in place and an inexperienced person could damage the equipment.

• 7 = Sensors or USB disconnect during lift off or descent
  – Disconnecting of devices due to gravitational forces would cause a mission failure if not handled correctly.

• 8 = Coding doesn't work after initial testing
  – After the testing is done the code was not up to par causing fixes and corrections to be completed.

• 9 = Arduino cannot recognize gravity pressure accurately to start power on sequence
  – The accelerometer is not made to handle the G-force being put out during liftoff causing a mission failure.

• 10 = Girls that code group doesn't want to participate
  – In the end they decide it’s too much work and quit not harm done.
Risks

- 11 = Lego structures come in overweight
  - Lego casings coming in overweight can either be an easy or a hard fix depending on the glue being used to hold it together.
- 12 = Lego's break in space environment
  - The Lego technology breaking in space environment will result in a mission failure.
- 13 = System cannot operate in cold environment
  - The whole system could freeze over if not properly insulated or tested.
- 14 = Original testing not adequate for space conditions
  - We fail to test how the system will react in a shuttle do to inexperience could result in huge delays.
- 15 = Lego wants in on the project and tries to take over
  - The company that sells the project may want to partake and could try to control the experiment to insure success. doing this could result in major delays.
• 16 = Batteries fall out during descent
  – Batteries were not secured enough and come out of the casing during the descent causing partial mission failure.
• 17 = Sponsor and other group members being too busy to meet on a regular basis
  – This is bound to happen with any group project but properly manage should not cause much delays.
• 18 = Moldings don’t fit technology available
  – We get our measurements wrong for the Legos and have to remold. This causes days of valuable time gone.
• 19 = NXT Brick doesn’t recognize other lego technology
  – Not likely to happen but the NXT Brick stops recognizing its own technology casing a mission failure.
• 20 = Sensors and technology go out of range for specified
  – This is going to happen when looking at the specs, however the mission is not to actually measure temperatures but to test Lego technology in space.
System Design – Weight Budget

• Present your subsystem weight and total weight similar to what is given at the right.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lego NXT Brick</td>
<td>0.351</td>
</tr>
<tr>
<td>6x AA batteries</td>
<td>0.2866</td>
</tr>
<tr>
<td>USB Memory Storage</td>
<td>0.06875</td>
</tr>
<tr>
<td>Lego Mindstorms Temperature Sensor</td>
<td>0.08818</td>
</tr>
<tr>
<td>Arduino Accelerometer</td>
<td>0.055116</td>
</tr>
<tr>
<td>Lego NXT Barometer</td>
<td>0.0044</td>
</tr>
<tr>
<td>Lego Housing/ Other</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total (lbs)</strong></td>
<td><strong>1.854046</strong></td>
</tr>
<tr>
<td><strong>Over/Under</strong></td>
<td><strong>(0.145954)</strong></td>
</tr>
</tbody>
</table>
# System Design – Power Budget

## SCHOOL/ORG - 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>Lego NXT Brick</td>
<td>3.3</td>
<td>.4</td>
<td>15</td>
<td>1.32</td>
<td>0.10</td>
</tr>
<tr>
<td>6x AA batteries</td>
<td>9</td>
<td>16.8</td>
<td>15</td>
<td>151.20</td>
<td>4.2</td>
</tr>
<tr>
<td>USB Memory Storage</td>
<td>5</td>
<td>.5</td>
<td>15</td>
<td>2.50</td>
<td>.125</td>
</tr>
<tr>
<td>Lego Mindstorms Temperature Sensor</td>
<td>5.5</td>
<td>.05</td>
<td>15</td>
<td>0.275</td>
<td>0.0125</td>
</tr>
<tr>
<td>Arduino Accelerometer</td>
<td>5</td>
<td>0.02</td>
<td>15</td>
<td>0.10</td>
<td>0.005</td>
</tr>
<tr>
<td>Lego NXT Barometer</td>
<td>5</td>
<td>0.112</td>
<td>15</td>
<td>0.56</td>
<td>0.028</td>
</tr>
</tbody>
</table>

<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><strong>Total</strong></td>
<td><strong>1.082</strong></td>
<td><strong>15</strong></td>
<td><strong>4.755</strong></td>
<td><strong>0.2705</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total Power Capacity</strong></td>
<td><strong>16.8</strong></td>
<td><strong>15</strong></td>
<td><strong>151.2</strong></td>
<td><strong>4.2</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Over (+)/Under (-)</strong></td>
<td><strong>15.4918</strong></td>
<td><strong>15</strong></td>
<td><strong>146.445</strong></td>
<td><strong>3.9295</strong></td>
<td></td>
</tr>
</tbody>
</table>
Manufacturing Plan
Tyler McGee, Carlos Alexander, Trinite Klamadji
What needs to be manufactured?

- System will be bought separately and put together by our team. The Lego NXT computer will need disassembled to be encased into our Lego pieces to fit requirements allotted.

What needs to be procured?

- USB 2.0
- Arduino Accelerometer
- Lego Mindstorms Temperature sensor
- Lego NXT Barometer
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Date Started</th>
<th>Date Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Procurement</td>
<td>All equipment and parts needed will be procured</td>
<td>01/12/18</td>
<td>01/19/18</td>
</tr>
<tr>
<td>Equipment Test Assembly</td>
<td>Equipment will be assembled in order to test functionality</td>
<td>01/19/18</td>
<td>02/01/18</td>
</tr>
<tr>
<td>Lego Case Assembly</td>
<td>Custom Lego Case will be assembled in order to fit all parts properly</td>
<td>02/01/18</td>
<td>02/14/18</td>
</tr>
<tr>
<td>Equipment Installed inside Lego Case</td>
<td>All equipment will be installed in Lego case</td>
<td>02/14/18</td>
<td>02/28/18</td>
</tr>
<tr>
<td>Equipment Test</td>
<td>Equipment is tested again in order to assure functionality</td>
<td>03/01/18</td>
<td>03/15/18</td>
</tr>
</tbody>
</table>
Electrical Elements

What needs to be manufactured/soldered?

• The System just needs assembled using the ports the NXT Brick already has.
• The manufacturing that will need done is connecting the Arduino Accelerometer to the battery supply to operate as a start up switch during takeoff and the actual lego housings that will be used.

How many revisions of the electronics do you anticipate?

• We plan on two revisions of the electronics. The first is if the Arduino Accelerometer will not be compatible and the second is if we would like more accurate readings by using more advanced Lego compatible Technologies.

What needs to be procured - For more accuracy (just in case)?

• 2x Lego NXT Vernier Adaptor
• Vernier Thermocouple
• Vernier 25-g accelerometer
# Electrical Element Schedule

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Date Started</th>
<th>Date Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor and Arduino Procurement</td>
<td>All sensors and Arduino needed to record data will be procured</td>
<td>01/12/19</td>
<td>01/19/18</td>
</tr>
<tr>
<td>Sensor Testing</td>
<td>All sensors will need tested in order to assure they are functioning properly</td>
<td>01/20/18</td>
<td>02/10/18</td>
</tr>
<tr>
<td>Arduino Testing</td>
<td>Arduino will be tested in order to assure functionality and compatibility</td>
<td>01/20/18</td>
<td>02/10/18</td>
</tr>
<tr>
<td>Sensor Installation</td>
<td>All sensors will be installed in Lego Case</td>
<td>02/11/18</td>
<td>02/28/18</td>
</tr>
<tr>
<td>Arduino Installation</td>
<td>Arduino and force switch will be installed to Lego board and power supply</td>
<td>02/28/18</td>
<td>03/16/18</td>
</tr>
<tr>
<td>Full System Test</td>
<td>All systems will be tested to insure all equipment is working properly in Lego case</td>
<td>03/16/18</td>
<td>04/08/18</td>
</tr>
</tbody>
</table>
What discrete blocks of code need to be completed?

- Blocks of code are not interdependent. The Lego NXT board will have separate coding for each sensor that will run on its own.

Which blocks depend on other blocks?

- As of now, all blocks of code should run dependently from one another. The Lego NXT board will control all sensors independently.
- The only actual programming that will be needed will be with the Arduino in order to get the force switch working properly.
- Arduino will most likely be programmed in C++ or Java.
## Software Element Schedule

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Date Started</th>
<th>Date Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Procurement</td>
<td>All equipment and parts needed will be procured</td>
<td>01/12/18</td>
<td>01/19/18</td>
</tr>
<tr>
<td>Sensor Testing</td>
<td>All sensors will need tested before programming can begin</td>
<td>01/20/18</td>
<td>02/10/18</td>
</tr>
<tr>
<td>Lego NXT programming</td>
<td>All sensors will be programmed to record data on a microSD card using the Lego Mindstorm NXT interface</td>
<td>02/10/18</td>
<td>02/28/18</td>
</tr>
<tr>
<td>Arduino programming</td>
<td>Arduino will be programmed with force switch in order to work with NXT board</td>
<td>02/28/18</td>
<td>03/28/18</td>
</tr>
<tr>
<td>Arduino Testing</td>
<td>Arduino programming will be tested with full system and sensors</td>
<td>03/28/18</td>
<td>04/12/18</td>
</tr>
<tr>
<td>Final System Assembly</td>
<td>Full system will be assembled and tested</td>
<td>04/12/18</td>
<td>05/01/18</td>
</tr>
</tbody>
</table>
Testing Plan

Tyler McGee, Carlos Alexander, Trinite Klamadji
Mechanical Testing

• Mass verification test
  – System will need to be tested in order to verify weight requirements
  – Will be tested by placing final system on a scale

• Dimensions verification test
  – System will be required to meet the specified dimensions
  – Will be tested with a ruler or tape measurer
Mechanical Testing

Test Date

—The tests will be performed at least a month before the system is due to allow time for contingencies.

Success Measures

—The tests will be successful if the system is under the required weight and if it fits inside the required dimensions.
Electrical Testing

Arduino Accelerometer Test
• This test will verify if the Arduino accelerometer will be compatible with the power supply and the Lego computer
• This test will also verify if the gravity switch is operational
• Test will be conducted by simulating the rockets g-force changes
• Test will be performed at least two months before the deadline
• Will be a success if the switch turns on when it senses gravitational changes

Arduino Compatibility Test
• This test will verify if the Arduino will fit and will be compatible with the custom Lego case
• This test will be conducted by trying to fit the Arduino into the Lego case’s dimensions
• This test will be performed at least two months before the deadline
• Success will be measured if the Arduino fits inside of the case
Arduino Software Test

• The Arduino will need to be programmed first in order to be compatible with the Lego board
• Test will be conducted by programming the Arduino then plugging it in and seeing if it is operational
• Test will be completed at least 3 months before deadline
• Test will prove successful if Arduino operates accordingly with the Lego NXT
System Level Testing

Fit Check Test

- Will verify whether or not board and sensors will fit inside custom Lego case
- Test will be conducted by setting board inside case and determining whether it will fit
- Will be successful if all parts fit inside case

Sensor Integration Test

- Will verify whether or not the sensor will integrate properly with the board
- Test will be conducted by attaching sensors to board and determining if they are working properly
- Will be successful if all sensors are properly working after integration
Glue Durability Test

- Will verify whether or not the Lego glue will withstand the sub-zero temperatures of space
- Test will be conducted by placing glued structure in a temperature simulated environment
- Will be successful if the structure stays together after the test

Test Details

- Test will be done at least a month before deadline submission
- All system level tests will be conducted by the project team
- The tests will be performed at Fairmont State or the NASA IV & V Facility
Project Summary

- Areas of concern

  - This project is very challenging and since lego robotics has never been flown in space, we are concerned that our case might not be able to last with the extreme conditions of space.

  - We are also concerned about some of the materials that we need for our payload (some of them might be a little overweight and we might need to find alternative solutions).
Worries

• We hope that the glue we’re using to keep our whole construction together will be strong enough and will fulfill its purpose.
• We’re still working on the method we will use in order to turn on our payload once it’s launched in space.
• If we decide to go for more accuracy ensuring that everything will come under weight will also be a problem.
Conclusion

• What’s your plan of action at this point?
  – We plan on procuring the items that we need and getting acquainted with the rest of the project team to set up meeting times and set up a reasonable schedule.
• What are you going to try to get done before (or potentially during) winter break?
  – Catch up on this project to get to a very comfortable spot for next semester.
  – Communicate with everyone to set up a good plan of action with contingencies in place for struggles.
Space Flight Design Challenge
Critical Design Review

West Virginia University
National Society of Black Engineers

Team Co-Leads: Francis Mbuyamba, Morgan Cassels
Team: Emily Certain, Selorme Agbleze, Kyle Gillis, Lunet Yifru, Ferron Campbell, Chai Smith, Temitope Agboola
12/1/2017
Mission Overview
Mission Overview

- **Mission statement**: Our mission is to collect and store real-time flight data (altitude, temperature, pressure, trajectory, rotation, and speed of the rocket).

  - To gather altitude, temperature and pressure values, a BMP 280 Adafruit sensor will be used.
  - To determine trajectory and angular rotation, a MMA8451 3-axis accelerometer coupled with a L3G20H 3D gyroscope will be used.
  - To calculate the speed values, results from the gyroscope and the BMP 280 sensor will be used.

- We plan to gather a variety of data to better understand the movement and trajectory of rockets.
Theory and Concepts: Altitude and Velocity

- The MMA8451 3-axis accelerometer will measure the acceleration of the rocket. The velocity can be determined from the acceleration and thus the distance travelled and also the altitude can also be calculated using the equations of motion.

  - \( r \) - position
  - \( a \) - acceleration
  - \( v \) - velocity
  - \( t \) - time

Theory and Concepts: Temperature

For temperature between 0 - 11 km use the following equation: \( T = 288.16 - 0.0065h \)

For temperature between 11 - 25 km use the following equation: \( T = 216.6 \) K

For temperature between 25 - 47 km use the following equation: \( T = 216.66 + 0.003(h - 24902) \)

For temperature between 47 - 53 km use following equation: \( T = 282.66 \) K

For temperature between 53 - 79 km use following equation: \( T = 282.66 - 0.0045(h - 53000) \)

For temperature between 79 - 90 km use following equation: \( T = 165.66 \) K

For temperature between 90 - 350 km use following equation: \( T = 165.66 + 0.004(h - 90000) \)
The L3G20H 3D gyroscope has a default set axis. To determine the spin of the rocket the sensor will measure how quickly a particular axes changes with respect to time.

The gyroscope coupled with the MMA8451 accelerometer will measure the pitch of the rocket thus allowing us to determine the trajectory of the rocket.

During the entire flight, altitude data, temperature data, pressure data, trajectory data, rotation data, and speed data will be gathered.
Expected Results

Final Calculations:
10 readings per minute*15 minute flight= 150 readings
a reading will be taken every 6 seconds

<table>
<thead>
<tr>
<th>Unit</th>
<th>Expected Max Value</th>
<th>Expected Min Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>altitude</td>
<td>115 km</td>
<td>0 km</td>
</tr>
<tr>
<td>temperature</td>
<td>300 K</td>
<td>260 K</td>
</tr>
<tr>
<td>pressure</td>
<td>101.325 kPa</td>
<td>0.0001 kPa</td>
</tr>
<tr>
<td>rotation</td>
<td>336 RPM</td>
<td>0 RPM</td>
</tr>
<tr>
<td>speed</td>
<td>640 m/s</td>
<td>0 m/s</td>
</tr>
</tbody>
</table>
Expected Results: Temperature

The 1976 Standard Atmosphere Above 86-km Altitude Recommendations of Task Group II to COESA
Expected Results: Pressure

Figure 21. Total pressure versus altitude, 86 to 150 km.

The 1976 Standard Atmosphere Above 86-km Altitude Recommendations of Task Group II to COESA
Success Criteria

• Comprehensive Success: to capture the altitude, temperature, pressure, trajectory, acceleration and angular velocity.
• Minimum Success: to capture one data type without any malfunctions
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The GPS shall gather data every 6 seconds</td>
<td>Test</td>
<td>The code must instruct the GPS to capture and store data every 30 seconds. To test this, data for the length of the final flight must be collected.</td>
</tr>
<tr>
<td>The components must stay intact during the flight</td>
<td>Test</td>
<td>The payload must be tested at high speeds to ensure all components will stay intact.</td>
</tr>
<tr>
<td>Arduino will take readings from all sensors and store them on SD card</td>
<td>Test</td>
<td>Data will be stored in a matrix.</td>
</tr>
<tr>
<td>Continuous power needs to be provided to the arduino</td>
<td>Test</td>
<td>Run arduino for the duration of the flight (15 min).</td>
</tr>
<tr>
<td>Connections need to be secure and should stay intact throughout flight</td>
<td>Inspection/Test</td>
<td>After vibration test, the relevant adjustments can be made.</td>
</tr>
<tr>
<td>All major connections to arduino should not be loose connections</td>
<td>Inspection</td>
<td>Tape or sealant can be used to secure connections, if needed.</td>
</tr>
<tr>
<td>Requirement</td>
<td>Verification Method</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pressure sensor will begin recording Pressure at launch</td>
<td>Test</td>
<td>The code will use pressure reading to compute temperature and altitude</td>
</tr>
<tr>
<td>Sensor should run continuously throughout the flight</td>
<td>Demonstrate</td>
<td>Every 6 seconds a new a computation is done to find corresponding temperature and altitude</td>
</tr>
<tr>
<td>Sensor shouldn’t be exposed to ports or holes</td>
<td>Inspection</td>
<td>Sensor will be placed closest to the center of canister</td>
</tr>
</tbody>
</table>
System Overview
System Components

• Structure:
  – Screws and Wires
  – Breadboard

• Power:
  – Battery connector

• Control System:
  – Arduino Uno

• Sensor System:
  – Accelerometer
  – Altitude/ Pressure/ Temperature Sensor
  – Angular velocity Sensor (gyroscope)
Changes Since PDR

- We decided to use an Arduino rather than a Raspberry Pi, for easier sensor to control interfacing
- We decided to no longer use a camera in the experiment
- These changes do not change any of our mission objectives/requirements.
Block Diagram

System Layout

Arduino Uno, clock, SD card

MMA8451

BMP280

LG320H

3V Battery
Mechanical Design

*Stacked layers < 1.25 in
Software Flow Diagram

Start

- Collect Acceleration data from MMA8451
  - Calculate inclination
  - Trajectory is determined from speed and inclination

- Collect pressure data from BMP280
  - Calculate Velocity and distance
  - Altitude is determined from trajectory

- Collect angular velocity from L3GD20H
  - Determine which temperature formula to use

- Calculate temperature
  - Store data to SD card

End
Control System Design
Control System Design: Arduino UNO R3
Control System Design: Arduino UNO R3

- We picked the Arduino UNO because of its capabilities as well as its simplicity when it comes to programming and interfacing.
  - Open source software.
  - Multiple sources to learn from
  - Can control a variety of sensors
  - Cheaper than the initially proposed Raspberry Pi
- The Arduino can be purchased online from the RobotShop (http://www.robotshop.com/en/)
Control System Design: Arduino UNO R3

• The Arduino has all the required ports and connections
  – 6 Analog pins (2 for each sensor)
  – Digital pins for storage system

• Risks;
  – We aren't certain of the functionality of the Arduino at high altitudes.
  – Arduino only allows for loose connections, that could disconnect during flight
Control System Design: Clock

• This is the clock that will be used to start and stop experiment
  – Requires 5V power to work
  – Pins may need to be soldered onto board
  – Can be ordered from Adafruit
  – Weight: 2.3 gram

• Can be purchased from Adafruit ()

RBpEiwApLGUirsjpiGl3TWO3jmZHzRi117otOSR60LbdOpErW3GDUicWBeqAvNB7RoClBYQAvD_BwE
Final Control System Design:

- Arduino Uno: 2.7 in x 2.1 in
- Adafruit Clock: 1 in x .85 in
- Micro SD card board: 1.25 in x 1 in
### Risk Matrix – Control System

<table>
<thead>
<tr>
<th>Consequence</th>
<th>RISK 1</th>
<th>RISK 2</th>
<th>RISK 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possibility</td>
<td><img src="yellow_square" alt="" /></td>
<td><img src="orange_square" alt="" /></td>
<td><img src="red_square" alt="" /></td>
</tr>
</tbody>
</table>

**RISK 1:** Loss of power to the Arduino

**RISK 2:** Failure to maintain connection between Arduino and sensors

**RISK 3:** Failure to save data to SD card
Sensor System

• We have 3 sensors and one storage device
• These components were selected mainly for their relative simplicity to use and program
• The following criteria was used in selecting the sensors;
  – Price
  – Arduino compatibility
  – simplicity
• The sensors are final but may change with mission requirements
Subsystem Design: Adafruit BMP280

This is a barometric pressure sensor board:

- Measures barometric pressure
- Sensor comes with a 3.3V regulator which makes for easier interfacing
- Pins may need to be soldered onto board
- Can be ordered from Adafruit
- Weight: 1 gram
- Altitude Range: -500 m to 90000 m
- This sensor may be substituted with one with a greater altitude range

Adafruit BMP 280 Sensor
Subsystem Design: Adafruit MMA8451

This is a accelerometer board

- Measures Acceleration and tilt
- Sensor comes with a 3.3V regulator which makes for easier interfacing
- Pins may need to be soldered onto board
- Can be ordered from Adafruit
- Weight: 1.3 gram
- The only issue is correctly using the dated read from accelerometer in the software program

Adafruit MMA8451 Sensor
Subsystem Design: Adafruit L3GD20H

This is a 3 dimensional gyroscope board

- Measures angular velocity
- Sensor comes with a 3.3V regulator which makes for easier interfacing
- Pins may need to be soldered onto board
- Can be ordered from Adafruit
- Weight: 2.02 gram
- The only issue is correctly using the dated read from gyro in the software program

Adafruit L3GD20H Sensor
Subsystem Design:
Adafruit MicroSD card breakout board+

This is a microSD card board

- Allows data to be stored and Read on to microSD card
- Sensor comes with a 3.3V regulator which makes for easier interfacing
- Pins may need to be soldered onto board
- Can be ordered from Adafruit
- Weight: 3.43 gram
- This is the final option for the storage system

MicroSD card breakout board+
Final Sensor System Design:

- **BMP280**: 0.8 in x 0.7 in
- **MMA8451**: 0.8 in x 0.7 in
- **L3GD20H**: 0.75 in x 1.2 in
Risk Matrix – Sensor System

RISK 1: Environmental damage to the sensors

RISK 2: Failure to maintain sensor connection during flight

RISK 3: Failure to save sensor data
Power Design
Power Design: 3V Coin Cell Battery

3V CR1220 Coin Cell battery
Power Design

- Clock that is going to activate the whole system requires a 3v coin cell battery.
- This was a user recommended battery that works well with the clock
  - Risks: 3V Coin Cell:
    - The Coin cell battery not fitted correctly in place
- The Clock and Cell can be purchased online at https://www.adafruit.com/
Risk Matrix – Power

RISK 1: Wiring to components becomes disconnected during flight

RISK 2: Batteries become disconnected during flight

RISK 3: Batteries run out of power during flight
## System Design – Weight Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino UNO</td>
<td>25</td>
</tr>
<tr>
<td>BMP280</td>
<td>1</td>
</tr>
<tr>
<td>MMA8451</td>
<td>1.3</td>
</tr>
<tr>
<td>L3GD20H</td>
<td>2.02</td>
</tr>
<tr>
<td>MicroSD board</td>
<td>3.43</td>
</tr>
<tr>
<td>DS1307</td>
<td>2.3</td>
</tr>
<tr>
<td>3V Coin Cell</td>
<td>0.8</td>
</tr>
<tr>
<td>Bread Board</td>
<td>83.7</td>
</tr>
<tr>
<td><strong>Total (kg)</strong></td>
<td><strong>0.11855</strong></td>
</tr>
</tbody>
</table>
### Subsystem Design – 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>Arduino UNO</td>
<td>5</td>
<td>0.045</td>
<td>60</td>
<td>0.225</td>
<td>0.045</td>
</tr>
<tr>
<td>DS1307</td>
<td>5</td>
<td>0.0015</td>
<td>60</td>
<td>0.0075</td>
<td>0.0015</td>
</tr>
<tr>
<td>BMP280</td>
<td>3</td>
<td>2.7*10^-6</td>
<td>20</td>
<td>8.1*10^-6</td>
<td>9*10^-3</td>
</tr>
<tr>
<td>MMA8451</td>
<td>3</td>
<td>8*10^-5</td>
<td>20</td>
<td>240*10^-6</td>
<td>2.6*10^-5</td>
</tr>
<tr>
<td>L3GD20H</td>
<td>3</td>
<td>5*10^-3</td>
<td>20</td>
<td>15*10^-3</td>
<td>1.6*10^-3</td>
</tr>
<tr>
<td>Micr SD card board</td>
<td>3</td>
<td>5*10^-3</td>
<td>60</td>
<td>15*10^-3</td>
<td>1.6*10^-3</td>
</tr>
<tr>
<td><strong>Total Power</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>15 Watts</strong></td>
<td></td>
</tr>
</tbody>
</table>
Prototyping & Analysis
Analysis and Prototyping Results/Plan

• What was analyzed/tested since PDR?
  – all components were analyzed for:
    - size
    - weight
    - compatibility
    - Capability

• Prototyping in progress:
  • CAD design of payload

• Plans for other prototyping activities?
  • Exact weight measurements in CAD design
  • Center of gravity measurements in CAD design
Manufacturing Plan
Payload Elements

- What needs to be manufactured?
  - The entire payload must enter the manufacturing phase. This is planned to begin the second semester.
  - The manufacturing of the payload will begin Week 1 of the Spring semester and last until Week 4 of the Spring semester.
  - this leaves ample time and resources for testing and changes
Testing Plan
## Payload Testing

<table>
<thead>
<tr>
<th>Test of:</th>
<th>What will this verify?</th>
<th>Components Involved</th>
<th>Test Pass Requirements</th>
<th>Scheduled start date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino code</td>
<td>The ability of the code to guide the payload Arduino and sensors correctly</td>
<td>Arduino</td>
<td>Correct performance of each sensor from code</td>
<td>Week 5</td>
</tr>
<tr>
<td>Power</td>
<td>The ability of the batteries to power the payload for the duration of the final flight (without sensors attached)</td>
<td>batteries</td>
<td>power for the entire final flight length</td>
<td>Week 6</td>
</tr>
<tr>
<td>sensors</td>
<td>the ability of each sensor to meet the expected performance standard while individually connected to power and the Arduino</td>
<td>batteries, sensors, Arduino</td>
<td>Successfully saving the desired amount and quality data of each individual sensor</td>
<td>Week 7</td>
</tr>
<tr>
<td>SD card/data</td>
<td>the ability of the SD card to save the amount and quality of data desired</td>
<td>Arduino, batteries, sensors</td>
<td>Successfully saving the desired amount and quality data of all sensors</td>
<td>Week 8</td>
</tr>
<tr>
<td>Power</td>
<td>The ability of the batteries to power the payload for the duration of the final flight (with sensors attached)</td>
<td>Arduino, batteries, sensors</td>
<td>power for the entire final flight length</td>
<td>Week 9</td>
</tr>
</tbody>
</table>
De-Scopes and Off-Ramps

- To minimize the cost of the project, the scope can be reduced to gather minimal data.
- To minimize the scope of the project, minimal data can be gathered.
- To minimize the time taken to complete tasks, laddering and splitting of tasks can be utilized.
Conclusion

Plan of action:
• Model the payload in CAD
• Weigh the components when they are received (for verification)
• Continue in depth research on each component
• Interview previous participants and observe their lessons learned
• Begin manufacturing process
Space Flight Design Challenge Critical Design Review

West Virginia University
Cameron Hale, Emily Certain, Jeffrey Moe,
Troy Pallay, William Howard

December 1, 2017
CDR Presentation Content

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

• Section 2: System Overview
  – Requirement/Design Changes Since CDR
  – Mechanical Design Elements
  – Port Design Elements (if applicable)
  – Electrical Design Elements
  – Software Design Elements
  – De-Scopes/Off-Ramps
CDR Presentation Contents

• Section 3: Subsystem Design
  – Subsystem A (SSA) (i.e. EPS)
  – Subsystem B (SSB) (i.e. STR)
  – Etc.

• Section 4: Prototyping/Analysis
  – Analysis Results
    • Interpretation to requirements
  – Prototyping Results
    • Interpretation to requirements
  – Detailed Mass Budget
  – Detailed Power Budget
CDR Presentation Contents

• Section 5: Manufacturing Plan
  – Mechanical Elements
  – Electrical Elements
  – Software Elements

• Section 6: Testing Plan
  – System Level Testing
    • Requirements to be verified
  – Mechanical Elements
    • Requirements to be verified
  – Electrical Elements
    • Requirements to be verified
  – Software Elements
    • Requirements to be verified
Mission Overview

[Jeffrey Moe]
Mission Overview (Updated)

● Mission statement
  ○ Collect and transmit via Amateur Radio telemetry data during the flight.
  ○ Receive transmitted data at several scattered stations to track propagation as RockSat moves through the layers of the atmosphere

● Requirements
  ○ Collect GPS data
  ○ Process data
  ○ Transmit & receive
Mission Overview (Updated)

● Expected Results
  ○ Real-time tracking of RockSat

● Who will this benefit/what will your data be used for?
  ○ Our data will be verified with NASA’s own telemetry data in order to verify that our system provided coherent and accurate data
  ○ Tracking of propagation data will further knowledge of how RF signals move through our atmosphere
Mission Overview: Mission Objectives

• Mission Objectives \(\rightarrow\) derived from mission statement
  – Collect via GPS unit telemetry data
  – Process data via on-board systems
  – Transmit data
  – Receive data at Wallops and propagation testing stations
Theory and Concepts

• Amateur Radio operators around the world transmit data daily over several established data protocols.
• White paper published by the ARRL describes the doppler shift experienced by rockets moving at high velocity
• GPS unit automatically corrects for doppler shift
• WVU professor and researcher Dr. Gross has used GPS modules in past projects related to the university.
Theory and Concepts (cont’d)

• Radio waves propagate through the atmosphere in complex ways
• In general, communication are expected to be received in line of sight of the transmitter
Concept of Operations (Updated)

- Simple payload staging
- Once flight begins, the payload will continuously receive, process, and retransmit data until splashdown.
Expected Results *(Updated)*

• Accurate telemetry data
• At least one data point per second
• Allow for other university amateur radio clubs to listen in (collection of propagation data)
Success Criteria (Updated)

• Minimum Success Criteria:
  – Capture of at least one valid (readable) data point for every 10 seconds of flight time.

• Comprehensive Success Criteria:
  – Capture of at least one valid (readable) data point for every second of flight time
Functional & Design Requirement Guidelines

● GPS receiver
  ○ Novatel GPS unit
  ○ ~900MHz
  ○ Needs to be delimited and registered with the export control office.

● Transmission
  ○ Two antennas
    ■ one for ground station transmission
    ■ one for further broadcasting

● GPS processing
  ○ Single Board Computer (SBC) embedded solution
  ○ Raspberry Pi Zero
## Functional Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The SBC shall be properly interfaced with all the components</td>
<td><strong>Analysis</strong></td>
<td>The system will be connected through an SWR meter and tested.</td>
</tr>
<tr>
<td>The GPS unit shall function correctly above the limit velocity and altitude</td>
<td><strong>Demonstration</strong></td>
<td>The system will be connected to a flight simulator and the results recorded.</td>
</tr>
<tr>
<td>The full system shall fit on a single RockSat-C Can</td>
<td><strong>Inspection</strong></td>
<td>Visual inspection will verify this requirement</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-C program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
System Overview
System Definitions

- SBC: Single Board Computer
- RTS: Rocket Transmission System
- RRS: Rocket Reception System
- GPS: Global Positioning System
- PSK: Phase Shift Keying
- DCS: Data Collection System
Changes Since PDR

• What major changes have you made since PDR?
  – Why were these changes made?

• Do these change any of your mission objectives/requirements?
System Level Block Diagram

Rocket Transmission System (RTS)

Data Collection System
- GPS (Var. 1)
- Var. 2

Data Processing System
- Pi Zero

Data Transmission System
- TNC
- Transmitter
- Antenna
Mechanical Design Elements

- Show final payload design with labels and dimensions
  - If you have made changes since PDR, discuss why you made them and how it affects your mission requirements
- Was anything not modeled?
- How do you know this design will survive flight?
Electrical Design Elements

• Please show finalized **block diagrams**, state how many PCBs/breadboards you will use and what each one will do, sensors they will have (multiple slides)

• Do you have schematics? If you show them, talk about them (specifically critical components/connections). If you don’t, be sure to at least answer the question!

• Any changes to this system since PDR? (1-2 slides)

• How does this affect your mission requirements?

• What has been finalized that wasn’t at PDR?
Software Design Elements

- The program will need to account for I/O between the GPS module and the transmission antenna.
- The software will also perform signal processing on data received from the GPS module, transform the data into transmittable data. The transmittable data will then be handed off to the transmitting antenna.
De-Scopes and Off-Ramps

- The scope of the project is still the same.
  - Receive data from GPS Module.
  - Process telemetry information with raspberry pi
  - Transmit information to the base station.
  - Receive information at the base station
  - Receive transmission from other amateur radio clubs.
De-Scopes and Off-Ramps

• The Primary goal of the mission is to process telemetry.
• The secondary mission is to have other radio stations other than the base station also receive transmission data.
• If not enough volunteers want to receive data from the transmission, the secondary mission will not be possible.
• If an adequate GPS module is not available for the project, data could be incorrect.
Special Requests

- RF is required for this project as it is the method of communication from the rocket to the base station
- Our project requires an outside port for at least one transmission antenna.
Subsystem Design
Subsystem Design Section

• This section is where you explain how each subsystem was designed
• Start with your organization chart with each of your subsystems labeled
• Discuss how you researched components that would meet your requirements
  – Show trade studies if necessary, and if you show them, be prepared to explain the scoring and categories
• The most important part is explaining how you reached your major design decisions in each subsystem
• After explaining components, discuss any risks associated with this subsystem
Subsystem Design Section Notes

• Interfacing
• Software & Signal Processing
• Transmission
• Receiving
Subsystem Design

Interfacing

Troy Pallay
Subsystem Design – Interfacing

• All subsystems will require exchanging data
• The Interfacing subsystem will allow this to happen
Risk Matrix – Interfacing

RSK.1: Data lines are misplaced.
RSK.2: Connections come loose due to vibrations
Subsystem Design

Software & Signal Processing

William Holland
Subsystem Design – Software & Signal Processing

• A Raspberry Pi Zero will be used to process data from the GPS system
• This processed data will be sent to the RTS for transmission to ground
Risk Matrix – Subsystem Design – Software & Signal Processing

RSK.1: Program corruption
RSK.2: Logical Bugs/errors
Subsystem Design

Transmission (RTS)
William Howard
Subsystem Design – Transmission

- The RTS will use on-board antennas to transmit processed data to the ground at Wallops
- Data will also be received at various stations on the eastern coast
Risk Matrix – Transmission

RSK.1: Unable to transmit due to electrical damage.
RSK.2: Unable to transmit due to mechanical damage.
Subsystem Design

Receiving
Cameron Hale
Subsystem Design – Receiving

• Flight data will be received at a Wallops-based ground station
Risk Matrix – Receiving

RSK.1: Unable to receive transmission due to adverse conditions
RSK.2: Unable to receive transmission due to malfunctioning equipment
Subsystem Design – Weight Budget/Power Budget

• Currently we do not have an estimate on the total weight or power consumption of the system.
Prototyping & Analysis
Analysis Results/Plans

- Analysis since PDR
  - GPIO signal output stability of the Raspberry Pi Zero with regard to vibrations.
    - A 100Hz signal was generated from a GPIO pin on the Pi via python script.
    - The Pi was bolted onto a vibration apparatus and the output measured with an oscilloscope.

- What are the key results?
  - The 100Hz signal remained stable throughout the experiment.

- How do these results relate to the project requirements?
  - Vibrations in sounding rockets are assumed to be a problem, therefore by applying this experiment we have determined a Raspberry Pi Zero will be sufficient for this project.
Prototyping Results/Plan

• Future Prototyping
  – There is a potential opportunity next semester to test the system in conjunction with the WVU Rocketry club.
  – Beginning next semester, prototyping and software development will begin.

• Benefits of Prototyping
  – These opportunities to prototype and test will become very important in the design and details of the project.
Manufacturing Plan
Mechanical Elements

- Manufactured
  - For final subsystems, PCB’s will be created

- Procured
  - Prototyping materials such as perfboard, electrical components, the GPS module, a transmission and receive antenna, and elements needed for the base station.
Electrical Elements

• What needs to be manufactured/soldered?
  • Circuit boards, antennas.
• How many revisions of the electronics do you anticipate? (Be realistic)
  • At least three iterations of electronic design will be sufficient.
• What needs to be procured?
  • Perfboard, various electrical components, GPS module.
• Present a plan/schedule to get it done in time for testing.
  • Not yet completed.
Software Elements

- What discrete blocks of code need to be completed?
  - I/O interfacing
  - Signal processing
Testing Plan
Mechanical Testing

• All subsystems will be weighed individually and integrated
• Mass will be added to bring the payload to spec
• Components will be securely affixed to each other to prevent vibration damage
Electrical Testing

• Subsystems will be tested at +/- 20% rated voltage for consistency
Software Testing

- Software will be tested by simulating GPS data, processing it, and analyzing the output.
System Level Testing

- GPS Data received
  - We are looking for accurate data and precise location.
- Signal processing
  - Does the information from the GPS get transformed into usable transmission information?
- RX/TX
  - Can the data be properly transmitted and received without errors at a reasonable data rate?
- Interfacing
  - Are the modules properly connected with logical sense?
System Level Testing

• When will these tests be performed?
  • Preliminary testing will take place between the beginning of the spring semester and the middle of February.
  • The system will undergo a more rigorous test during a rocket launch later in the semester.

• Where will these tests be performed?
  • Preliminary tests will be done in the WVU ARC Shack
  • Rocket testing will be done at a location under the discretion of the WVU Rocketry Club.

• What will you need? Who will be doing it?
  • Required materials will depend on the bill of materials.
  • The Rocketry club has provided an opportunity to test our system on one of their rockets.
Project Summary

• Remaining issues
  – Final planning & system design is required.
    • Exact model of GPS unit to be used (more information on that very soon).
    • Exact dates/times which work can be done on the project during the spring.

• Areas of concern
  – Class assignments causing conflicts with project progress.
Worries

• Complete system failure
  – Failure at any subsystem could cause a breakdown for the entire system.
Conclusion

• Plan of Action
  – Acquire the necessary components.
  – Determine mass of components.
  – Determine electrical power consumption.
  – Schedule designated schedules for each subsystem.
  – Begin designing subsystem details & developing code.
  – Contact other radio clubs on the east coast.

• Winter Break tasks
  – Build a detailed schedule.
  – Assign tasks for each subsystem team.
Backup Slides

Include any slides that you may not have time for during the presentation, but could provide more information/help you answer questions or explain better (i.e. pictures, math, full requirements, etc..)
Purpose of CDR

• Confirm that:
  – **The design is mature enough to move into the fabrication phase**
  – Final analysis on systems that weren’t prototyped or needed further analysis is complete and accurate
  – Results of prototyping suggest the system will meet project requirements
  – Manufacturing plan is in place
  – Testing plan is in place and sufficient to ensure system functionality and performance in-flight
  – PDR risks have been walked down and to the left on a risk matrix (if possible)
  – Project meets requirements of RockSat-C user guide
  – The project is on track to be **completed on time** and within budget
**Presenting the CDR**

- 50%: This presentation focuses on why you designed the payload the way you did

- Most obvious explanation is so that it meets your mission requirements, but you need to explain how it does this
  - Don’t forget about off ramps, de-scopes, and design changes
  - Think about how to explain each design element from the how and why aspect

- 50%: The other half of the presentation is the execution of how you are going to do all of this, don’t forget about this half.
Writing Risks – a note

• When you write a risk, you are writing about the bad thing that might result, not the cause
  – Ex: “Risk 1: There might be one+ month delay in obtaining our science instrument” – not quite. This is the cause. The RISK is what this might do to your project, like delay testing, integration, schedule, etc., so you could write “Risk 1: The integration schedule will slip due to delays in procuring the science instrument”
System Design – Physical Model (Example)

Gyroscope
1.2" x 0.9" x 0.3"

Oscilloscope
1" x 1.5" x 0.25"

Piezoelectric Generator
2.3" x 1.1" x 0.0625"

Battery
0.8"DIA

Battery
0.8"DIA

Battery
0.8"DIA

Raspberry Pi 3
3.4" x 2.3" x 0.8"

10 DOF
1.5" x 0.9" x 0.125"

BRCTC-2017
Space Flight Design Challenge Critical Design Review

PAXC/MIT/GSK/UMN/UCLA
Andrew Gilstrap, Nicholas Bense, Orlando Gordillo, Olesya Nakonechnaya, Reeve Lambert
December 4, 2017
CDR Presentation Content

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

- Section 2: System Overview
  - Requirement/Design Changes Since CDR
  - Mechanical Design Elements
  - Software Design Elements
  - De-Scopes/Off-Ramps
• Section 3: Subsystem Design
  – Subsystem A (Scientific Payload)
  – Subsystem B (de-Orbiting Device)

• Section 4: Prototyping/Analysis
  – Analysis Results
  – Prototyping Results
  – Detailed Mass Budget
  – Detailed Power Budget
CDR Presentation Contents

• Section 5: Manufacturing Plan
  – Mechanical Elements
  – Electrical Elements
  – Software Elements

• Section 6: Testing Plan
  – System Level Testing
  – Mechanical Elements
  – Electrical Elements
  – Software Elements

• Section 7: Summaries
  – Project Summary
  – Worries
  – Conclusion
Mission Overview
Emily Certain
Mission Overview

• Our mission is to design and test our systems and payload within the capabilities of this sounding rocket in order to gather scientific results and troubleshoot the package for a longer duration cubesat experiment.

• Our mission requires access to the central power line, and if available, an antenna system for data telemetry.

• Our experiment has four fold potential for significant results, including a de-orbiting mechanism that has the potential to reduce the growing amount of orbital debris that may result from cubesat experiments, as well as a microfluidics experiment designed to observe channel occlusion due to protein aggregation, RNA folding, and synthetic protocell gene expression.

• This data has the potential to benefit a wide audience including future cubesat missions, medical/pharmaceutical research and development, and the field of astrobiology.
Mission Overview: Mission Objectives

• Mission Objectives
  – Test computing, data recording, and scientific payload microfluidics pump subsystems for cubesat
  – Test a locking mechanism for a novel de-orbiting device
  – Gather data from 3 separate microfluidics experiments operating in microgravity
Theory and Concepts

• When objects in low earth orbit slow down, orbital velocity decreases and earth’s gravitational force pulls the objects into the atmosphere causing them to burn up. However, with some launches, CubeSats initial acceleration is significant enough to keep the object in orbit for 25 years or more. De-orbiting mechanisms have been the solution to this problem where the cubesats are in orbit and have ended their mission purpose and no longer need to stay in orbit. Research has been performed and current NASA guidelines are being revised into requirements for such mechanisms to be included in the CubeSat missions.

• A microfluidics device has been developed for nano-precipitation of protein structures which may be quite difficult to resolve, however the device encounters channel occlusion due to what is believed to be the effects of Earth Gravity and Stoke’s Law. Examining the behavior of this microfluidics chip in microgravity may reveal more information and potential solutions regarding this problem.

• Recent research into “space gene” epigenetics through the NASA twin study have revealed a great need for investigation of all aspects of gene expression, including the effects microgravity may have on RNA folding mechanisms.

• Protocells have a wide variety of applications including metabolic production and astrobiology investigations. The effects of microgravity on gene expression from these proto-cells has not yet been examined.
A microfluidics device has been developed to assist in the nanoprecipitation of protein structures, however Stokes’ law can result in channel occlusion and thus investigations into the effects of a microgravity environment on this process could be highly valuable to this pharmaceutical development problem.

We can observe effects on the microfluidics lane through fluorescence microscopy at a magnification of 40x.

Parallel experiments on the ground in Earth’s gravity field will serve as a method of distinguishing significant results through comparison.
Current Fouling of Nanoprecipitation – Due to Gravity/Stoke’s Law?

$t = 0$ min

$t = 1$ min

$t = 2$ min

$t = 4$ min
Computational Flow Model
This experiment will monitor RNA folding in a microgravity environment through fluorescence imaging.

The proposed work employs RNA aptamers selected within the last several years. These aptamers activate the fluorescence of a cognate small molecule ligand that is not fluorescent except when bound to its aptamer target.

As the correctly folded RNA is required to activate the fluorescence, this enables us to observe RNA folding by fluorescence spectroscopy – a system that was not experimentally tractable until recently. A great deal of the existing literature on RNA folding employs circular dichroism – a measurement technique that is not amenable to miniaturization.

System allows us to monitor RNA folding in which the RNA experiences several folding half-lives within 10 min under Earth’s gravity.

We have successfully observed the fluorescence of these RNAs at the concentration range proposed, employing commercially available LED excitation sources and cell phone cameras.
Fluorescent RNAs

**RNA Spinach and RNA Broccoli**
- Binds small molecule mimic of the GFP core
- Folded RNA activates fluorescence of small molecule
- Functions in anaerobic conditions

*Science* (2011) 333 642-646
A solution of Broccoli aptamer (1 μM) and DFHBI (15 μM) in 40 mM tris-HCl, pH 8 were incubated for 10 minutes, then MgCl₂ and KCl were added to final concentrations of 100 mM each. The folding of the aptamer was monitored by fluorescence (λ<sub>ex</sub>=472 nm, λ<sub>em</sub>=507 nm).
Aptamer fluorescence visualized by readily available commercial means

We have visualized aptamer fluorescence using blue LED light sources and commercial cell phone cameras at concentrations spanning the range employed in folding experiments. Here, samples A-C were ca. 3 μM in aptamer, and sample D was ca. 300 nM.
Synthetic minimal cells (or “synells”) are liposomal bioreactors, with lipid membranes encapsulating protein synthesis machinery and genetic circuits.

A synthetic minimal cell is an encapsulation of protein synthesis system, with other enzymes and small molecules, inside semi-permeable phospholipid membrane.

The protein synthesis machinery can come from eukaryotic or prokaryotic source:
- Prokaryotic: low cost, efficient expression of simple proteins
- Eukaryotic: higher cost expression of complex modified eukaryotic proteins.

Synthetic cells can be used as basic science tools for astrobiology, a biomedical discovery and manufacturing platform, as biomimicry and biomanufacturing tools, or sensors and actuators for interacting with natural cells and the environment.

Synthetic cells provide designable and programmable biological system, enabling studying and re-designing biological processes.

Synell gene expression has never been evaluated in microgravity environments; this technology has potential application for protein production during long space flight missions.
Synell eGFP Protein Expression Observed through Fluorescence

Sample 1

Sample 2
ConOps

- Microfluidics pumps triggered
  \( t \approx 2.05 \text{ min} \)

**High Concentration of N\(_2\)**
- \( t \approx 1.3 \text{ min} \)
- Altitude: 75 km

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

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

**High Tumble Rate**
- \( t \approx 4.0 \text{ min} \)
- Altitude: 95 km

**Low N\(_2\), Low spin**
- \( t \approx 5.5 \text{ min} \)
- Chute Deploys

- Systems engaged
  - Camera/microscope start recording

**t = 0 \text{ min}**

**t = 15 \text{ min}**
- Splash Down
Expected Results

- Our project will establish tests for our various subsystems for use in a cubesat payload
- In terms of scientific results, we expect to observe reduced channel occlusion that we hypothesize is occurring in Earth gravity due to Stoke’s law
- We also expect to observe any differences in RNA folding that could have implications for human space adaptivity.
- Finally, we expect to observe the microgravity effects on protocells in a novel experiment to examine gene expression for metabolic engineering processes without interference from endogenous metabolism of natural cells, including metabolic engineering and biomanufacturing during long term space missions, and studies of biological pathways with astrobiology implications.
Success Criteria

• Minimum Success Criteria:
  – Functional subsystems for an operational payload and continuous video record of experiment

• Comprehensive Success Criteria:
  – Successful test of locking mechanism for de-orbiting mechanism, significant/observable scientific results from all 3 microfluidics experiments
## Functional Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The micropumps shall pump a continuous stream of fluid through the microfluidics device.</td>
<td><strong>Demonstration</strong></td>
<td>Test video of the pumping apparatus will be recorded to demonstrate effectiveness</td>
</tr>
<tr>
<td>The microscope camera system will record LED fluorescence to SD card and transfer data to the OBC for transmission</td>
<td><strong>Demonstration</strong></td>
<td>Sample data will be recorded from the assembly in Earth Gravity</td>
</tr>
<tr>
<td>De-orbiting mechanism</td>
<td><strong>Demonstration</strong></td>
<td>After the payload is extracted after recovery, the locking mechanism will be activated to verify that it survived the launch and did not prematurely trigger</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-C program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
<tr>
<td>The full system shall weight within the range of 19.8 to 20.2 lbs.</td>
<td><strong>Inspection</strong></td>
<td>System shall be put on a scale to determine weight.</td>
</tr>
</tbody>
</table>
System Overview
Andrew Gilstrap
System Definitions

• OBC: On-board computer (Raspberry Pi Zero)
• SP: Scientific Payload
• MFM: Mini-fluorescence microscope
• MD: Microfluidics device
Changes Since PDR

- The major changes we have implemented since the PDR include the refinement of the science payload experiment selections (to include three distinct experiments contained within separate lanes of a single microfluidics device) as well as the equipment that will be used to conduct these experiments.
  - These changes were made as the multi-disciplinary team expanded their scope and sought new collaborations to foster an experimental design of increased scientific value.

- The changes made have resulted in the selection of a microscopy system capable of detecting fluorescent molecules.

- The Deorbit Device has moved away from a flexible rod and spool method due to the bulk and low drag nature of our implementation. The system has moved to a rotating arm and membrane design.
System Level Block Diagram

Legend

- Data/Control
- 3V Circuit
- 1V Circuit
Mechanical Design Elements - De-Orbiting Mechanism

De-orbiting Mechanism
100mm *
100mm *
25mm
De-Orbiting Mechanism Arm Deployment
Mechanical Design Elements-
Deployed Topdown View
System Design – Physical Model
System Design – Physical Model
System Design – Physical Model
System Design – Physical Model
System Design – Physical Model
Software Overview

Orlando Gordillo, Olesya Nakonechnaya
OBC – Physical Model

Weight: 9 grams

CORNER RADIUS = 3.0mm

4x M2.5 MOUNTING HOLES DRILLED TO 2.75 +/- 0.05mm
OBC – Specifications

- 1GHz, Single-core CPU
- 512MB RAM
- Mini-HDMI port
- Micro-USB OTG port
- Micro-USB power
- HAT-compatible 40-pin header
- Composite video and reset headers
- CSI camera connector (v1.3 only)
Pi Zero Application Pin Layout

GPIO's 13, 19, 26, 16, 20, 21 shall be reserved to control 6 pumps for the MicroPump Experiment.

GPIO 12 shall be reserved for LED.

GPIO's 17, 27, 22 shall be reserved for MicroScope.

GPIO's 23, 24 shall be reserved for DeOrbiter.

*pigpio* is a C library for the Raspberry which allows control of the GPIO.
The operating system on the Raspberry Pi Zero shall be Raspian Jessie (Linux). We shall use Goddard’s open source core flight software (CFS) as the foundation of each experiment application. The core flight software uses OSAL to facilitate operating system calls and events. Aside from providing an interface to the operating system, the core flight software provides the following subsystems.

- **Executive Services** - initializes and control the applications
- **Software Bus** - A publish and subscribe messaging system based on CCSDS command and telemetry packets
- **Time Services** - Manages system time
- **Event Services** - Event reporting and logging services for applications
- **Table Services** - Data/parameter load and update services for applications

The CFS and the applications for the CFS shall be written in C. We will use a Git repository to version control the software and a test verification suite to verify and validate the software prior to launch.
CFS Applications

The core flight software shall manage the following applications:

- MicroPump Application
- MicroScope Application
- DeOrbiter Application

*Application Data shall be divided based on the needs of the experiment.

Total Disk Space shall be **128 GB**

- CFS 65 Mb
- MISC tools (Git, etc.) ~2 GB
- Operative System (Raspbian) 4.5 Gb
- *Application Data ~120 GB

*Application Data shall be divided based on the needs of the experiment.
Software Flow Diagram within cFS

Start the application(s)

MicroPump Application
- Start pumps (123 sec)
- Pump

MicroScope Application
- Turn on Camera (123 sec)
- Take picture based on interval

DeOrbiter Application
- Start timer
- Deorbiting device triggered
- Store Data for 777 sec

End
void pump(int num, char *pains)
{
    gpioInitialise();
    /* Set GPIO pins High*/
    for (i=1; i<num; i++)
    {
        g = atoi(pins[i]);
        gpioSetMode(g, PI_INPUT);
        gpioSetPullUpDown(g, PI_PUD_UP);
    }
}
Software Flow Diagram within cFS

- Start the application(s)
  - MicroPump Application
    - Start pumps (123 sec)
    - Pump
    - Take picture based on interval
  - MicroScope Application
    - Turn on Camera (123 sec)
    - Take picture based on interval
    - Store Data for 777 sec
  - DeOrbiter Application
    - Start timer
  
- Deorbiting device triggered
  - End

functions:

void takePicture(
  uint32 size,
  uint8 Buffer[],
  int *Pointer)

Input: Size, Buffer, Pointer
Image
return Pointer
Software Flow Diagram within cFS
De-Scopes and Off-Ramps

- The scope of this project has expanded to include three distinct microfluidics experiments.
- We have not had to sacrifice any mission objectives in order to complete our mission objectives in a timely manner. We do not foresee having to sacrifice any mission objectives to continue to meet our future deadlines.
- As our project has expanded to three separate microfluidics experiments, we are presented with the option to remove one or two of these experiments to reduce payload complexity.
- If the microfluidics component of the experiment does not handle vibration testing within acceptable parameters, further de-scoping is possible through removal of the scientific payload subsystem entirely.
Special Requests

• We would like to request accommodation to include small amounts of liquid on board our scientific payload with a total volume of approximately 90 mL.

• We would also like to include basic biological molecules within the microfluidics experiments (RNA and metabolic components for synthetic proto-cell gene expression).
Subsystem Design
Nicholas Bense
Science Payload
Current Experimental Setup

- 600uL/min 3% Polyvinylpyrrolidone in Water
- 15uL/min of 15mg/ml API in DMSO
- 4x Objective
- 10x Eyepiece
  (40x Total)
- Microscope Base
Current Experimental Setup
Cubesat Experimental Setup

- 600μL/min 3% Polyvinylpyrrolidone in Water
- 15μL/min of 15mg/ml API in DMSO

Reagent A: 15mL 3% PVP in H2O
Reagent B: 500μL API in DMSO
### Risk Matrix – Science Payload

<table>
<thead>
<tr>
<th>Possibility</th>
<th>Concern</th>
<th>SP.RSK.1</th>
<th>SP.RSK.2</th>
<th>SP.RSK.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td>Green</td>
<td>Yellow</td>
<td>Red</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>Yellow</td>
<td>Orange</td>
<td>Red</td>
</tr>
<tr>
<td>Extreme</td>
<td></td>
<td>Orange</td>
<td>Red</td>
<td>Red</td>
</tr>
</tbody>
</table>

**SP.RSK.1:** Mission objectives are not met if experiments do not produce observable results.

**SP.RSK.2:** Mission objectives are not met if microscope fails to properly record data.

**SP.RSK.3:** The experiment apparatus can’t survive launch conditions, and the mission objectives aren’t met.

**Mitigation**

- **SP.RSK.1:** Mission objectives are not met if experiments do not produce observable results.
- **SP.RSK.2:** Mini-microscope data systems will be tested for data collection.
- **SP.RSK.3:** The experiment apparatus will be subjected to vibrational testing.
Deorbit Device

Subsystem Design
Andrew Gilstrap
Deorbit Device Design

• Major System Changes
  – It was determined that the drag produced from the previous system would not significantly induce drag since electrodynamic forces could not be utilized on the rod system
  – Due to limited design time, a number of component applications used in other cubesat deployable rigid structures were utilized
  – The Deorbit Device moved to utilize a rotating arm with a Kapton membrane attached between arms to produce aerodynamic drag
  – Dyneema cords and extension springs are used to apply low torque to actuate the arms
  – Due to the nature of the geometry of the tension system, the system will have a very small volume compared to most cubesat deorbit devices
Deorbit Device Design

• Deployment
  – The Deorbit Device now utilizes tension lines and extension springs to deploy.
  – After the arms are released from the locking mechanism, a Dyneema cord attached to one edge of each arm is pulled by the extension spring until the arms reach a hardstop on the cubesat chassis.
  – Extremely low profile due to nested design

• Locking
  – To prevent actuation, a tie off point will be designed as a part of the cubesat chassis.
  – A Dyneema cord will be used to prevent the contraction of the spring.
  – The Dyneema cord being used to lock the spring will run over a nichrome wire, so that when power is provided to the nichrome the Dyneema cord will be cut, allowing the arms to extend
Deorbit Device Design

- Dynemema Cord Attachment

- Cord wrap around for a single arm
- Cords attached to both arms
Deorbit Device Design

• Future System Changes
  – Items like the springs, cord material, nichrome, arm geometry, deployment method, and locking method are all final
  – Minor component specifics will need to be changed
    • The pivots and washers for each arm
    • Clearance between arms
    • Interfaces with the cubesat chassis
    • Power-on time for the nichrome
    • Retention of Dyneema cords on arms
  – The difficulty with determining components specifics will be minimal since each require simple bench tests and hand calculations
Risk Matrix - Deorbit Device

<table>
<thead>
<tr>
<th>CONSEQUENCES</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDM.RSK.1: Nichrome fails to cut the Dyneema locking cord quickly</td>
<td></td>
</tr>
<tr>
<td>DDM.RSK.2: Arms do not actuate due to friction and clamp loads</td>
<td></td>
</tr>
<tr>
<td>DDM.RSK.3: Locking mechanism fails under vibration loads</td>
<td></td>
</tr>
</tbody>
</table>

Mitigation

- **DDM.RSK.1**: Perform cutting tests in vacuum chamber to validate cutting times
- **DDM.RSK.2**: Perform benchtop testing to ensure full actuation
- **DDM.RSK.3**: Oversize Dyneema locking cord and round all sharp contacting edges to the cord
## PAXC Sat Mass Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Structure</td>
<td>0.8</td>
</tr>
<tr>
<td>Deorbit Device</td>
<td>0.25</td>
</tr>
<tr>
<td>Scientific Payload</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Total (lbs)</strong></td>
<td><strong>1.5</strong></td>
</tr>
</tbody>
</table>

**Over/Under** 0.10/010
### SCHOOL/ORG- 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>Scientific Payload</td>
<td>3</td>
<td>6.5</td>
<td>10</td>
<td>2.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Deorbit Device</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4.09</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11.5</strong></td>
<td><strong>12</strong></td>
<td><strong>6.10</strong></td>
<td><strong>6.10</strong></td>
<td><strong>0.25</strong></td>
</tr>
</tbody>
</table>

**Subsystem Design – Power Budget**
Prototyping & Analysis
Nicholas Bense
Analysis Results/Plans

• Since the PDR we have developed a computational model for the flow dynamics of the fluids we will be using in the microfluidics device.

• Preliminary results of RNA and protocell gene expression fluorescence demonstrate that our experimental design parameters are compatible with the equipment choices we have selected.
Prototyping Results/Plan

• We have constructed and tested a syringe pump operated version of our microfluidics experimental apparatus

• Results display a working model/prototype of our design minus the mini-pump system and microscope camera recorder

• We plan to construct a prototype version of our final apparatus and subject it to stress testing to ensure optimal design
Manufacturing Plan
Andrew Gilstrap
Mechanical Elements

• We must assemble our pump apparatus and properly configure all components in the desired arrangement, as well as assemble the de-orbiting device

• Current timeframe is to begin assembly in January and finalize construction by February
Electrical Elements

• Our electronics structure is fairly simple and only requires interfacing between our off the shelf raspberry pi zero with our custom mini-microscope design

• We must also ensure our pump system, camera, and OBC are all wired properly to receive the desired amount of voltage/power

• We expect to be able to manufacture the electrical elements with minimal difficulty

• Current timeframe is to begin assembly in January and finalize construction by February
Software Elements

- Code must account for initializing of experiment as well as data storage through time-stamped cronjob/timer

- Error trapping and fail-safe mechanisms must be properly coded as well

- Current timeframe is to begin writing code in January and finalize construction by February
Mechanical testing will consist of ensuring the pump system is running properly by running complete experiments after the complete assembly is created, and by examining the deployment mechanism of the de-orbiting device to ensure it functions as intended. Cord cutting testing for the deorbit device will be performed to fully quantify expected cutting times.

These tests will be conducted periodically once the final apparatus has been assembled beginning in January/February and will continue up until the launch date.
Electrical Testing

- Electrical testing will consist of running complete experiments with the apparatus to gather results while measuring the voltage and power levels transitioning between each component of the comprehensive payload.

- These tests will be conducted periodically once the final apparatus has been assembled beginning in January/February and will continue up until the launch date.
Software Testing

• The software team shall define the functional requirements for each application.

• The software team shall create a design document to define the protocols for each unit in each application. These protocols will be written in formal/informal nature.

• A test matrix shall be created to document test cases for both unit and functional testing.

• These tests, together, will form the software verification suite and will be created once the final apparatus has been assembled beginning in January/February. Deadlines for verification tests will be determined once the tests have been conceptualized.
A verification test shall be one or many of the following tests.

- Functional testing: Testing against software requirements.
- Unit Testing: Unit testing shall be performed using utassert for code coverage.
- Peer reviews: Code shall be peer reviewed before being accepted into the master solution.
System Level Testing

- The microscope and microfluidics chip must be mounted accurately to ensure proper observation of results
- Vibration testing must be conducted on the assembled apparatus to ensure epoxied components are solidly constructed
- The microscope must remain functional and properly focused before, during, and after testing
- Electrical systems must be tested to ensure the mini-microscope and pumps are receiving the proper voltage and power requirements
- The apparatus will first be assembled and tested at GlaxoSmithKline’s facilities in Philadelphia, then tested again at MIT in January/February of 2018
Project Summary

• Our payload possesses incredible potential for creating significant scientific impact and contributing to the development of aerospace technologies for more effective cubesat experiment design through the de-orbiting device.

• We possess a finalized and prototyped design and now only require assembly and testing of our final apparatus.
Worries

- We need to conduct thorough stress testing to ensure our package possesses construction that holds up against rigorous vibration testing to ensure the liquid elements of our payload do not become a risk factor.
• The next step in our plan of action is to initiate purchase and assembly of the various components, and begin to conduct initial stress tests and experiment prototypes with a working apparatus

• Our immediate steps before and during the break will be to finalize ordering of the components and establish a time frame for manufacturing and testing of the final experiment apparatus
System Definitions

Our collaborative payload is comprised over several subsystems that are represented by each team’s individual payload along with standard operating subsystems.

– WVU-ARC Payload
– NASA-PAXC Payload
– WVU-NSBE Payload
– FSU Payload
– BRCTC Payload
– Power Distribution System
System Overview: Payload Layout

Structural Integration System

- WVU-ARC
- WVU NSBE
- FSU
- BRCTC
- PAXC

T-3 min activation switch (Wallops)

Power Distribution System

- Low Voltage 5.0 V
- Voltage Regulation +/- 12V
Using the same mechanical layout for our payload as last year:

Includes:
- Makrolon Plates
  - 4 subsystems on the bottom and 3 on top along with the power distribution board

Only change:
- We will be utilizing a mid mounting plate this year
Additional Mechanical Drawings

Top Down (Top Plate)  Top down (Bottom Plate)
Additional Mechanical Drawings

WVU-NSBE

WVU-ARC

FSU Double Stack PCB

PDB

Battery Pack

PAXC/BRCTC PCB Stack

Possible PiCam Outreach Payload to the School of the Deaf and Blind
Design Overview: Ports

Requested Port:

-Multipurpose Port

Reasoning:

-The WVU-ARC Team believes that this port would be the best fit for their small antenna for their RF propagation study
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can</td>
<td>(ballasts to be places strategically with shared can partner to ensure we maintain this compliance)</td>
</tr>
<tr>
<td>Contained in can</td>
<td>Yes</td>
</tr>
<tr>
<td>Connected to can by 4 or 5 bulkheads on top and bottom only</td>
<td>Yes</td>
</tr>
<tr>
<td>Mass at 10±0.2lbs</td>
<td>Yes (Predicted at 5lbs without ballast)</td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td>Yes</td>
</tr>
<tr>
<td>No voltage on the can</td>
<td>None (as of now)</td>
</tr>
<tr>
<td>No voltage on multipurpose port</td>
<td>None (as of now)</td>
</tr>
<tr>
<td>Activation wires at least 4 ft.</td>
<td>Yes</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>Yes</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>Yes</td>
</tr>
<tr>
<td>Battery Type</td>
<td>LiPo 7.4V 5000mAh</td>
</tr>
</tbody>
</table>
Design Overview: Shared Can Logistics

- We originally planned on sharing a canister with Hobart Williams Smith Colleges, but after learning more about their experiment decided that partnering would cause possible interference.

- Looking to possibly share a canister with Oregon again.

A mid mounting plate will be used and we have no preference of orientation.
Project Management
Emily Certain
Management: Org Chart

Emily Certain
Project Manager

Sebastian Reger
Deputy Project Manager

Jeff Reynolds
FSU Lead

Jeffrey Moe
ARC Lead

Ronald Willis
BRCTC Lead

Olesya Nakonechnaya
PAXC Lead

Morgan Cassels
NSBE Lead
<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/12/2017</td>
<td>Conceptual Design Review Teleconference</td>
</tr>
<tr>
<td>10/13/17</td>
<td>Earnest Deposit Due</td>
</tr>
<tr>
<td>10/13/17</td>
<td>Electrical Design Requirements Document Fabrication</td>
</tr>
<tr>
<td>11/2/17</td>
<td>Preliminary Design Review Teleconference</td>
</tr>
<tr>
<td>11/28/17</td>
<td>Protoyping Purchase Orders Fulfilled</td>
</tr>
<tr>
<td>12/15/17</td>
<td>Critical Design Review Teleconference</td>
</tr>
<tr>
<td>TBD</td>
<td>CDR Meeting with all SFDC Collaboration teams at NASA IV&amp;V</td>
</tr>
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</table>
## Management: Monetary 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>Devices</td>
<td>Various</td>
<td>$1000.00</td>
<td>6</td>
<td>$6,000.00</td>
<td>6 experiments kept under $1k each</td>
</tr>
<tr>
<td>PCBs</td>
<td>Advanced Circuits</td>
<td>$270.00</td>
<td>6</td>
<td>$1,620.00</td>
<td>6 subsystems require custom PCBs, expect 2 revisions each</td>
</tr>
<tr>
<td>Electronic Components</td>
<td>Digi-Key</td>
<td>$150.00</td>
<td>6</td>
<td>$900.00</td>
<td>1 set of components per 6 PCBs</td>
</tr>
<tr>
<td>Structural Supplies</td>
<td>McMaster-Carr</td>
<td>$400.00</td>
<td>1</td>
<td>$400.00</td>
<td>Only need 1 set of mechanical parts</td>
</tr>
<tr>
<td>Lab Supplies</td>
<td>Various</td>
<td>$70.00</td>
<td>6</td>
<td>$420.00</td>
<td>Allowance for lab supplies for each team</td>
</tr>
</tbody>
</table>

Total (no margin): $8440.00  
Total (w/ margin): $10,745.00
# Updated Team Availability Matrix

## WV-Collaboration

### Fall RS-C Team Availability Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
<td>4</td>
<td>3</td>
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<td>3</td>
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</tr>
<tr>
<td>8:00 AM</td>
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<tr>
<td>9:00 AM</td>
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<td>2</td>
</tr>
<tr>
<td>10:00 AM</td>
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<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11:00 AM</td>
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<td>3</td>
</tr>
<tr>
<td>12:00 PM</td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>3:00 PM</td>
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</tr>
<tr>
<td>4:00 PM</td>
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</tr>
<tr>
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</tbody>
</table>
Risks & Worries

Old

Finding a new shared canister partner that has an experiment we won’t interfere with (Hopefully Oregon Tech)
Conclusion

Overall, the mission of the Space Flight Design Challenge is to collaborate with institutions to foster innovative advancements in space payload design.

We are on schedule and over the holiday break we anticipate advancements in the protoyping aspects of each payload given that our first purchases for parts have been fulfilled.