NASA IV&V Team

Members:
Jared Wheeler, Ryan Dotson, Greg Lusk, Clayton Cobb

9/30/19
1.0 Mission Statement:

The Goals of The NASA IV&V team was to combine multiple teams onto one payload to create a team comprised of multiple smaller colleges. In doing this we would of liked to foster each team to create better designs each year. Along with this we hoped to get the younger students involved so that each year the experiments can get better and better.

2.0 Mission Description:

To foster innovative design within colleges and allow them to create more involved and complex experiments as the years go on.

Mission Requirements

a. Gather at least one set of data from one team
b. Create a payload that can house every team
c. Payload must survive throughout reentry.

3.0 Mission Results:

The success criteria of our mission was to be able to record some type of data from each team. And in the end we were successful with that minimum criteria. However, we went beyond that criteria and were able to record almost all data except after reentry (once again). We have concluded that this was either due to the battery losing charge during flight, or a payload pulling too much power from our PDS and in turn disabled the batter upon reentry.

In regards to the payload surviving, it did survive. However, there was a leakage in the payload once again this year. After multiple tests it was concluded that the cover plate we had used was leaking in multiple spots. The cover was slightly warped and this caused leaking upon splashdown. Along with that, the gasket used was uneven in some spots and therefore caused leakage.

4.0 Conclusions Results:

In conclusion the mission was successful, however it was not 100% successful/perfect. There were problems that occurred (such as power throughout reentry) that made some teams experiments unsuccessful. Such as HWS, they were unable to record outside temperature readings during reentry, and if they were they would have valuable data for future flights. However, for the NASA team we created a work payload, that was able to hold up through launch and was able to give each team some of the data that they needed. And with that, the launch was successful.
HWS RockSat-X

Students:
Joshua Andrews, Jasper White, and Elizabeth Moore

Advisors:
Ileana Dumitriu and Peter Spacher

Hobart and William Smith Colleges

9/5/19
1.0 Mission Statement:
The Goals of The HWS RockSat-X team was to measure the vibrations of the payload throughout its flight as well as measure the temperature of the payload following apogee and upon reentry. This would establish basic parameters for what payloads must withstand during reentry in the Earth’s atmosphere and provide useful information for teams in the future.

2.0 Mission Description:
HWS records the climate throughout the launch by measuring the temperature and vibrations of the flight through a thermocouple and triple-axis accelerometer.

Mission Requirements
a. The measurement vibration data must be recorded throughout the flight
b. The measurement of temperature must be recorded once the payload is exposed until touch down.
c. Our payload must receive power throughout the entire flight.

3.0 Payload Design:
HWS chose the Arduino Nano to log the data from their accelerometer and Temperature probe. The Adafruit MAX31865 RTD PT100 amplifier was utilized to gather the temperature as it had a range far beyond the expected temperatures throughout the flight. The Adafruit LSM9DSO Accelerometer was utilized to collect the vibrations data. The data was logged onto Adafruit’s Micro SD breakout board to ensure multiple back-ups of the data. All components were installed on a PCB manufactured by Advanced Circuits.
4.0 Student Involvement:
Joshua Andrews – Team Member, Physics & Philosophy
Elizabeth Moore – Team Member, Computer Science
Jasper White – Team Member, Physics & Electrical Engineering

5.0 Testing Results:
HWS conducted separate tests for the temperature probe (RTD) and the accelerometer prior to integration. The test for the RTD consisted of placing the temperature probe in environments with different known temperatures. The RTD was placed (1) in a cup that contained a mixture of water and snow, (2) in front of a hair dryer, and (3) in a room at room temperature. The known values for the temperature in these environments were approximately 0 °C, 60 °C, and 23 °C. Figures 1 and 2 display the results of the test for the RTD. The temperature probe recorded values within 1 °C of the actual values, and a sample of the data collected by RTD are presented below.

Figure 1: Results of the testing for the RTD.
The test for the accelerometer consisted of placing the accelerometer in the front seat of a car. While the car drove through the campus of HWS, the accelerometer recorded the acceleration of the car in the X (forwards and backwards), Y (left and right), and Z (up and down) directions. In order to ensure the accelerometer was recording readings for all three directions, the car went over speed bumps and around turns. The results of the changes in the acceleration of the car are shown in the graphs in Figures 3 and 4.

**Figure 2: RTD values taken by the temperature probe during testing.**

**Figure 3: Graph of the readings of the accelerometer while the car went over speed bumps.**

**Figure 4: Graph of the readings of the accelerometer while the car went around turns.**
6.0 Mission Results:
The success criteria for our flight included recording the temperature of the rocket throughout the total flight. In particular, we were interested in measuring the temperature of the payload following apogee and upon reentry. This is because the skin of the rocket would have been ejected after apogee, allowing our RTD, which was placed on the outside of our payload, to collect temperature measurements of space. Measurements taken before the skin was ejected represent the temperature of our payload, since the RTD was not directly exposed to space yet. After analyzing our data, we discovered that our project was only connected to power for the first 8 minutes of the flight. Therefore, we did not receive any temperature measurements following apogee and upon reentry. The results that we collected during the first 8 minutes of flight are shown in Figure 5.

![Temperature Graph](image)

**Figure 5: The temperature of the rocket throughout the first 8 minutes of flight.**

Prior to liftoff the temperature was fairly constant at about 23.60°C. At liftoff there is a slight dip in temperature before it reaches the highest recorded temperature of 23.87°C at 4.6 minutes into the flight. Then the temperature drops steadily until just after 8 minutes when it reaches a temperature of 14.49°C before it then appear to increase steadily until we lose power at about 8.5 minutes, presumably when the rocket begins to return back towards Earth.

A second goal for our mission was to measure the vibrations of the payload throughout its flight. Similar to the temperature readings, we were only able to record vibration values for the first 8 minutes of the flight. While we did collect data for those first 8 minutes, it appears
that the sensor either malfunctioned or was pushed beyond capacity, so it was unable to retrieve accurate data. According to Figure 6, the accelerations were pushed far beyond what would be expected or could be believable. We received data reaching all of the way beyond 16E6 m/s², as pushed beyond its

![Figure 6: The three separate Axis of acceleration data recorded for the first 8 minutes of the flight.](image)

7.0 Conclusions Results:
Due to our payload not receiving power for the whole flight, we were unable to collect results for the temperature and vibration of the rocket throughout the whole flight. The data that we were able to collect shows that before the skin is ejected, the temperature inside the payload increases steadily. One can presume that the temperature would continue to increase until splashdown as indicated in the last half minute of the graph (Figure 5). However, this cannot be proven from the collected data since our data only represents part of the rocket’s flight.

8.0 Benefits to the Scientific Community:
If our mission was successful, we would be able to provide basic parameters to other RockSat teams for what temperatures and vibrations their payloads must withstand for future experiments. This would allow them to make sure that their payload design is suitable enough for the conditions that it will endure during flight. This is important because every team wants their payload to be successful.

Due to the lack of power following 8.5 minutes we cannot truly determine the temperature ranges throughout the flight, nor consider any type of forces the payloads may be exposed to as payload returns to Earth. We would hope to maintain power throughout the flight in the future so we would have a better understanding the conditions of the payload as it returns to Earth.

9.0 Lessons Learned:
The HWS team learned many important skills associated with engineering fields that would not be afforded to them otherwise at a small liberal arts institution. These skills include creating mechanical drawings in Inventor, generating PCB board designs on Eagle, soldering electrical components into a PCB board, and working with both the hardware and software applications of Arduinos.

Team organization was definitely another important component of this project. As two of the three members were only on campus for half of the academic year due studying abroad and
their academic program, effectively organizing and managing the project became very crucial early on. Each member learned to be effective at communicating issues that needed to be resolved as well as working efficiently with the little time where all three members were in the same room together.
West Virginia State University

Provide hands-on experience with designing and building space related experiments and prepare for potential future CubeSat missions by comparing component designs

Jon Musselwhite, Shaka Wilkerson, Oddai Gharib, Taylor Jones-Martin, Elizabeth Carrier

Marek Krasnansky, Ph.D.

West Virginia State University

30 August 2019
1.0 Mission Statement

Provide hands-on experience with designing and building space related experiments while preparing for a possible CubeSat mission. Compare an array of Geiger tubes to determine their performance in space. Determine the orientation of the rocket relative to radiation sources using solid-state particle detectors. Determine the orientation of the rocket relative to the sun using solar panels.

2.0 Mission Requirements and Description

As a member of the WV Collaboration, the WVSU portion of the mission was restricted to a removable circuit board in the main enclosure and several auxiliary experiments on the payload deck. All power and data resources were to be shared between the several components. The auxiliary experiments included three Geiger circuit boards, an optical array, and a Si particle detector array.

The main circuit board was restricted to 3.25” by 4” with a no-go zone restricting that further to 3” by 4”. The no-go zone was used to align the main circuit board with the enclosure, so it could be easily inserted into and removed from the main enclosure. A specialized connector was required to be placed in the middle of one of the short ends of the board. That connector was used to interface the main circuit board with the backplane of the enclosure.

The Geiger circuit boards were limited to no more than 1” by 5” with a vertical height restriction of 1”. They also required mounting holes which could be used to attach the board to the payload deck. The high voltage circuits on the auxiliary board were required to be conformal coated in a way that isolated them and reduced the risk of voltage leaks.

The optical array and Si particle detector array were each required to occupy no more than 2”x2”x2”. They were to be placed on the edge of the payload deck such that the three faces of the solar panels had a clear line-of-sight.

3.0 Payload Design

Multiple separate experiments were taking place as part of this payload. The first experiment was to compare the performance of various Geiger tubes in space. One of the Geiger tubes were placed both inside the enclosure and outside the enclosure with the rest of the tubes. This allowed for an evaluation of the effects of the enclosure. The second experiment evaluated the feasibility of using solar panels to determine the orientation of the rocket relative of the Sun. A third experiment attempted to determine the direction of sources of radiation. A temperature/pressure sensor was included inside the enclosure to monitor the pressurization of the enclosure and determine the temperature extremes. An Inertial Measurement Unit (IMU) was included inside the enclosure to aid in evaluating the timing of events compared to the exact moment of launch. See below for a functional block diagram (Figure 1) of the experiments.
A primary development goal was to make everything modular such that individual modules could be replaced with ease. The main circuit board (Figure 2) was designed with pin header sockets used to connect the microcontroller and sensor modules, and an SO-DIMM socket used to connect the Raspberry Pi CM3.

The central control unit of the payload was an Arduino MKRZERO. It was connected to a Raspberry Pi Compute Module 3 (RPi CM3) Single Board Computer (SBC) using the UART communication protocol. The RPi CM3
inserted its own timestamp and transmitted data out the telemetry line in the main connector.

The IMU was an Adafruit 9-DOF Precision Inertial Measuring Unit which was configured to use its most sensitive settings for gathering readings of acceleration, magnetic field, and rate of rotation. This decision was a trade-off because the greater sensitivity resulted in a reduced range of possible values. Since the data from the IMU was intended to correlate the direction of sources of radiation, greater precision was chosen over greater range. The data it produced was gathered by the Arduino MKR ZERO over an I2C communication bus.

The Geiger comparison experiment consisted of four separate Geiger circuits. Two of the Geiger circuits utilized the same LND713 tube. One of those circuits was mounted on top of the microcontroller inside the enclosure. The other was placed outside with the remaining two Geiger circuits. The two other independent Geiger circuits utilized a SBM20 and SBM21 tube. Each Geiger circuit was independent from the rest. A single signal pin for each Geiger circuit was connected to the MKR Zero microcontroller. Each tube used an identical circuit design (Figure 3), which was selected during development due to its use of a 555-timer chip which offloaded some work from the microcontroller. Each circuit had a 5v pin, a ground pin, and a signal pin. The MKR ZERO microcontroller used the signal pin to determine when a radiation detection event had occurred by detecting a small surge in voltage.

![Figure 3: Schematic of Geiger circuit](image)

The Si particle detectors used a pair of pins for signal and noise. The signal pin was used to detect a drop of voltage which occurred during a detection event, and the noise pin showed activity when the signal data may have been corrupted by noise created by vibrations.

### 4.0 Student Involvement

Jonathan Musselwhite, a Computer Science major, was team lead and responsible for the software aspects of the project. Taylor Jones-Martin, a Chemistry major, was responsible for the Geiger comparison experiment. Shaka
Wilkerson, a Computer Science/Mathematics dual major, was responsible for the optical orientation experiment. Oddai Gharib, a Chemistry major, was responsible for the Si particle detector experiment. Elizabeth Carrier, an English major, was responsible for researching Geiger tubes and preparing posters and presentations.

5.0 Testing Results

Each experiment section was tested independently and the whole group was tested together to evaluate the microcontroller’s ability to keep up with the data flow.

The Si particle detectors were tested with an oscilloscope (Figure 4). Those tests demonstrated a clean signal. The detectors were further tested with a microcontroller reading the signal (Figure 5). The test results were nominal.

Figure 4: An oscilloscope showing an Si particle detector’s detection event
Figure 5: An Si particle detector being tested on a microcontroller

The Geiger-Mueller tubes and circuits were also tested with an oscilloscope (Figure 6). Those tests demonstrated a clean signal, which was fine-tuned during testing. A microcontroller was used to evaluate the Geiger circuits individually (Figure 7). The test results were nominal.
The optical orientation experiment (Figure 8) was tested with a microcontroller and a light source (Figure 9). The test results were nominal.
The microcontroller was tested for its ability to transmit reliably over UART. It was connected to a digital logic analyzer (Figure 10), which read its output (Figure 11). The test results were nominal.
Figure 10: The microcontroller connected to a digital logic analyzer

Figure 11: The output from the digital logic analyzer
The RPi CM3, mounted in a prototyping board, was connected to the microcontroller (Figure 12) to test the two components’ ability to communicate. The results of these tests were nominal.

![The RPi CM3 and microcontroller](image)

**Figure 12: The RPi CM3 and microcontroller**

### 6.0 Mission Results

Power was lost 40.58 s after launch and as such the shell of the rocket was still on for the duration of all data collection. The optical sensors weren’t able to detect sunlight; any fluctuations (Figure 13) of the signal can be explained by blinking LEDs from other experiments on the flight deck.

![Comparison of Optical Sensors X, Y, Z vs Time](image)

**Figure 13: The comparison of optical sensors shows semi regular fluctuations which could be the blinking of LEDs from other experiments on the flight deck**
There was low radioactivity such that the Geiger-Mueller tubes were only able to detect a small amount of ambient radiation (Figure 14) from the time the experiments started receiving power until power was lost. The SBM-20 showed the most activity, the SBM-21 showed the least, and the LND713 showed little difference between inside and outside the enclosure.

**Figure 14: A comparison of the 4 individual G-M tubes used in the experiment**

The Si particle detectors weren’t able to reliably detect signal due to excessive noise from vibrations during launch.

The accelerometer was only able to detect up to 20 m/s² but the readings that were obtained (Figure 15) clearly show the moment of launch from the z direction, the acceleration up to the release of the first stage. Then several seconds go by where acceleration decreases then another jump at 17 s where the second stage activated. The x and y components showed increased acceleration as the rocket began to rotate and the limit of the device was reached and was constant. The z direction showed a decrease in acceleration after 29 s indicating the end of the second stage.
Figure 15: The acceleration determined by the IMU in three axes

The magnetometer performed quite well in producing clear signal in the x and y directions (Figure 16). The total value is given by Earth’s magnetic field and magnetic field of devices within the rocket. The frequency change is due to the change in angular velocity. The amplitudes of the oscillations were used to estimate Earth’s magnetic field in the horizontal direction which gave a value of 18.5 μT from the x component of the magnetometer and 18.2 μT from the y component. The data from the z direction isn’t enough to estimate the vertical component of Earth’s magnetic field.

Figure 16: Magnetometer readings used to estimate the Earth’s magnetic field

The x and y directions of the gyroscope (Figure 17) showed the vibrations of the rocket. The z direction showed the launch, the end of the first stage, the rocket slowing down rotation, then the second stage.
Figure 17: Readings from the gyroscope indicating angular velocity

Temperature sensor inside the enclosure (Figure 18) detected little change as expected, but the pressure sensor showed a decrease in pressure which indicates a leak in the seal of the enclosure.

Figure 18: Temperature and pressure over time

7.0 Conclusions

Each component worked the way it was supposed to during the time that power was supplied, and some valuable information was obtained during the first 40.58 s after the launch. We were not able to determine the reason of the sudden power failure as all our devices didn’t show any deviance from the expected operation.

8.0 Potential Follow-on Work

Because experiments were not able to take measurements for the duration of the flight, the same experiments will be repeated during the next launch. Future
work will include simplifying the payload, including an independent and reliable power supply, and using components with a greater range of operation.

9.0 Benefits to the Scientific Community

Being aware of the source and amount of radiation is critical to any human flights in the upper atmosphere and in space. Significant progress was made in designing smaller reliable Geiger counters.

10.0 Lessons Learned

We’ve learned that a fully manufactured version of the payload should have been tested much earlier in the process. Even though this introduces additional expenses, it allows for the opportunity to correct problems much sooner in the development cycle.

We’ve learned to focus on power stability. Power was lost soon after launch, leading to a loss of data. We’ve learned that it would be important to include a stable power supply, possibly a battery, right from the start.

We’ve learned that some of the external mounts used this year were substandard and plan to produce more stable mounts in the future.
WVWC SPACE Club

To fly a Geiger counter experiment to measure the cosmic rays incident on the Earth

Student Names: Kaylee Burdette, Rich Calo, Joel Carty, Baylee Senator, Justin Bibey, Rian Bigsby, Noah Osborne, Andrew Wilhelm

Advisor Names: Tracey DeLaney

West Virginia Wesleyan College

Submittal Date
9/28/19
1.0 Mission Statement (0.5 page)

This experiment attempted to mirror the experiments in which cosmic rays were first discovered (although on a rocket and not a high altitude balloon), and the data collected was to be directly compared to NASA’s data. Overall goals were to get usable data that could be used for comparison, and hopefully give some information about the rocket’s relative position within Earth’s magnetic field.

2.0 Mission Requirements and Description (1-2 page(s))

The Geiger counter was intended to measure high energy particles due to radioactive decay of materials close to Earth. The count rate was predicted to rise and fall over the course of the flight path according to the relative distance of Earth’s surface radioactivity and then due to the presence of cosmic rays from the solar wind, galactic high energy sources such as supernova remnants, and extragalactic sources such as active galactic nuclei. Where the rocket was located in relation to the Sun mattered because the solar wind distorts Earth's magnetic field. Due to the nature of this particular experiment, there were no special requirements. The Geiger counter was on and recording for the duration of the flight.

3.0 Payload Design (2 – ??? pages)

The final setup for the Geiger counter experiment was relatively simple. It involved the Geiger counter itself affixed in a plastic case onto the outside of the payload deck, and the signal output from the Geiger (as well as voltage input to the Geiger) led from a PCB inside the payload with an Arduino and an Openlog with a microSD card to receive and record the data. Earlier iterations of the setup included an amplification circuit which was ultimately scrapped when the Geiger counter was replaced, especially because of the additional noise added with the addition of the circuit. The Arduino code was adjusted to take samples every second with the Geiger counter and to compile them into 60 second chunks for readability. The weight of this project was minimal, with each component being in the tens of grams. The cost of this project was around $300 with both Geiger counters factored in, but the materials actually used for the flight equalled just over $200.
Kaylee Burdette, Physics - Team Lead, main tester, soldering, reviews and powerpoints, various tasks
Rich Calo, Physics - Secondary Lead, main soldering and mechanical setup, review assistance
Joel Carty - Electrical and Mechanical Lead, initial drawups of the Geiger holder
Rian Bigsby - Software Lead, dealt with Arduino code
Baylee Senator, Justin Bibey, Noah Osborne, Andrew Wilhelm - Team members, provided soldering help and some other various tasks
5.0 Testing Results (1 – 2 page(s))

The Geiger counter experiment was tested using 0.1 microCi sources of Cesium-137. The Geiger counter and sample were tested with different orientations (source to the side, in front, behind) to determine if orientation mattered as for counts detected. Orientation did end up mattering slightly as the larger side surface area of the Geiger tube allowed for more particles to actually go into and be recognized by the Geiger counter. The source was also moved progressively farther away to try and see how distance of the source affected the sensing. The Geiger counter stopped detecting the source at a distance of about 12 cm, proving that it was very insensitive.

The graph displays the counts per minute relative to the distance as compared to the inverse square law. The graph displays a clear downward trend.

6.0 Mission Results (4-?? pages)

The data retrieved from the SD card was entirely zeros for the duration of the flight. While we were recording data for the entire flight, the Geiger counter was unable to detect any Cosmic rays, most likely because of the known insensitivity of the Geiger counter. The Geiger counter had also come out of its casing when the payload was retrieved, so there is a small possibility that the Geiger circuit fell off mid-flight, resulting in no data. The payload did not function as designed.

7.0 Conclusions (0.5 to 1 page)

The Geiger counter during testing could not detect any radiation unless a direct radioactive source was very close, which did not bode well for the detection of any radiation in the atmosphere. This was determined to be the most likely cause of failure. There is also, as discussed above, a chance that the single screw affixing the Geiger to the casing came loose very early into the flight and the Geiger counter was simply not present for the majority of the flight. As there
wasn’t any issue with vibration testing, it is much more likely that the Geiger system simply wasn’t sensitive enough for any detection to occur.

8.0 Potential Follow-on Work (0.5 to 1 page)

Any follow up work should involve equipment more sensitive than a small Geiger counter to detect radiation. Since Geiger counters’ efficacy decreases with a decrease in size, this experiment would work much better with a larger counter, although that might not be practical for this payload. Further work on cosmic rays might benefit from using scintillation detectors or other more sensitive and specific radiation detectors.

9.0 Benefits to the Scientific Community (0.5 to 1 page)

Had the experiment worked, we would have been able to compare our data to data of the magnetic field itself to get an idea of the rocket’s flight path and the magnetic field variations along it.

10.0 Lessons Learned (1 to 2 page(s))

If this payload were to be flown again, we would not be so quick to dismiss any sensitivity issues in testing. We would also ensure that the Geiger kit was more secure than we had it this time (while in a plastic casing, the kit itself was only affixed with a single screw. The casing itself, affixed with more screws, survived the flight). We would also look into more sensitive counters, and try to do testing without a direct radioactive source to more accurately mimic what would be found on a flight.
BRCTC Space Team

The experiment, designation BRCTC Vibe, is a vibration experiment that seeks to record vibrational data from the launch of the sounding rocket. Vibe data will be used to analyze Hertz data within the experiment enclosure throughout the flight.

From left to right

Students: Alberto Torres, Chris Sibole, Willis, David Wells, Walter Willis, Ronald Willis, Corey Hummer (not pictured), and Justin Shay (not pictured)

Advisor: Gervase Willis (pictured on the right)
1.0 Mission Statement

The goal of BRCTC Vibe is to successfully record an accurate vibration profile (Power Spectral Density or Frequency Analysis) of the canister in the rocket to provide vital hertz data to future Rocksat teams. We expect to record accurate, high resolution hertz data which will be presented on paper and in an animated VR environment.

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 of the vehicle. When this occurs in a mechanical system, sensitive electronics can de-calibrate and catastrophic damage can occur. We wish to keep future teams informed on what to expect from the enclosed environment to mitigate potential damage to experiments.

We wanted to design a pragmatic experiment with useful data. Many teams design high risk experiments with fantastic scientific research and well-made electronics. We thought it would be different and interesting to keep developing an experiment that can be immediately useful to NASA and future teams, while also being informative and a challenge for the team.
2.0 Mission Requirements and Description

This mission required key components for full mission success. We needed at least 1 gyroscope that could provide us with orientation and acceleration data, 3 single axis accelerometers, or both. All components with moving parts and sensing capabilities needed to be able to withstand up to 50g at the least. We also needed a main controller, a UART to communicate data, possibly an ADC, a RTC, and possibly an OP amps if we chose to use the piezoelectric discs from last year.

Accelerometer

Real Time Clock
Analog to Digital Converter

Gyroscope
Accelerometers/piezos were required to sense mechanical oscillations, especially at a low price and with limited space. A gyroscope is 3 accelerometers, one for each axis, calculated to show orientation and acceleration, which is why we wanted a gyro on board. While the gyro is not a requirement, it provides data on in-flight conditions, so it increases the resolution of the experiment, which makes it an asset to the mission.

We required processing power that could record, store and communicate data simultaneously, so we decided from the conceptualization of the experiment to use a Raspberry pi 3B+. The RTC was used to keep track of time to notate changes in the sample rate over the course of the mission. This would allow me to compensate for irregularities in the sample rate caused by overhead load on the processor. There simply wasn’t enough space for multiple controllers and multiple save devices that are more typical with smaller single function
controllers. The surface area needed to be reducible if the main enclosure ended up having defects after fabrication.

3.0 Payload Design

I (Ronald) had a design in mind for this project since conceptualization. This project has been my brain child for 2 years now. The design is quite simple; a main board to house the ADC, RPi, RTC, Gyro, and UART. The 3 accelerometers would be fastened directly to the inside of the enclosure, one on each axis. Design progression:
Our original design is an improved design from last years’ experiment, incorporating a compact design in case we were required to shrink a little. We recorded usable data last year, so the design was already proven to work. The only aspects I wanted to improve upon were adding the ability to transmit data in case the rocket was lost and designing independent accelerometers, one for each
axis. After researching piezoelectric discs, we investigated how to create custom accelerometers.

Changed piezo holder to enclosed casing to hold piezo and add known mass

During our investigation, we found that a known mass and more calculation was required in constructing useful custom accelerometers. We also
learned there was a UART built into the RP 3B+, so we tested to see which was easier to interface with, program, and send data with.

Switched to COTS accelerometers to save time, increase reliability and guarantee a specified sensitivity and resolution.
After a lot of research, we decided to off ramp the custom accelerometers to save time and use the UART built into the RP 3B+ because it was superior to the independent UART. During this time, I had realized there were discrepancies between what I had designed and was supposed to be integrated into the enclosure. After double checking sizes and designs, I requested enclosure information and discovered that the enclosure was designed with the incorrect dimensions, meaning our experiment had to be reduced in size.

After working with Jared and Ryan, I was given the size of the enclosure space and was able to match the dimensions given to them by the mechanical team at WVU. After designing and ordering a new set of boards and soldering components, I sent the experiment for testing. Unfortunately, the enclosure
details given to me were not accurate, so my new board needed to be cut for initial integration.

During the first integration, I traveled with My advisor to measure the enclosure myself to verify accurate measurements. After taking measurements and working with Jared and Ryan, we were able to accurately detail the enclosure space. Upon returning home, I got to work on the final revision of the experiment.
Final design to compensate for enclosure manufacturing error
The final design, seen above, was designed and sent for fabrication. There was not enough room for the ADIS Gyro, so I designed a new board to be placed next to the Z axis accelerometer and shortened the length of the main board. Unfortunately, the mechanical design team didn’t know how to fabricate the enclosure to include the fastened components, so they had to design a 3D printed holder for the accelerometers and the ADIS Gyro (I was informed of this after sending the final revision for final integration), which was adhered in place in the enclosure. The last-minute addition of the 3D holder also meant a reduction in space, so we had to off-ramp the ADIS Gyro this year. I had Walter remove it’s code from the larger body of code as a precaution. The accuracy of the readings was reduced by the 3D holder, but not by a large amount. The frequency of the wave form is distinct enough to easily be seen on the Z axis with little distortion.

Most of my design changes were more to overcome challenges for integration, rather than to suit the functionality of the experiment itself. It was a frustrating, but also useful challenge. Having the experience of changing an experiment last minute is vital experience for needing to solve issues on the fly in R&D prototyping, so I am happy for the experience.

Weight and power were well below what was available, so we did not have to worry about affecting other experiments.
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4.0 Student Involvement

Ronald Willis – Team, Electrical, Mechanical, Design, and Fabrication Lead. Throughout the experiment, I checked all physical systems, approved them, and designed all but a few specific 3D models. We had teammates that had to leave, or focus on work, so I made sure everything except code was perfect.

Walter Willis – Code Lead. Walter wrote and designed all software for the project. His work was invaluable to the project.

David Wells – Mechanical. David had to leave in the early stages of the experiment, but he assisted Chris on measuring components and designing the first 3D model.

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Unfortunately, it took over a month to receive flight data from Wallops, so we were not able to finish the VR interface. We needed gyro data to replace what
we lost from the ADIS gyro off-ramp. However, we will be finishing the program in the next month or so and will be adding a full video on it for all teams to see. It was a lot more difficult to figure out how to run a proper frequency analysis with over 4,000,000 data points, so last week I had to change my approach and use excel to analyze the data 4,096 data points at a time. It took a while, but with the help of Dr. Jeffrey Denenberg from Fairfield University, who graciously assisted me on Quora, I was able to use the Fourier transform and measure up to 4k Hz with excel. I am currently speaking with him to see if he might be willing to assist me by providing instruction on how to use a specific program to analyze the entire data set at one time. The data below was recorded at 8,035 samples per second.

Findings:

Terrier burn at .5 second intervals on Z axis
Looking at the vibrations, we see that on both motor burns that we reach vibrations up to 3,180 Hz. Lower Hz signals seem to increase in frequency at intervals of 60 Hz up to 480 Hz. During motor burn the initial oscillations are low frequency and then spread into higher frequencies.
Counterintuitively, I am glad that I had troubles translating this data because you can see how quickly the wave form changes over time, especially in this one example.
Malemute motor zoomed in 1,800 Hz to 4,000 Hz from 1.5-3.5 seconds

Terrier motor 1,800 Hz to 4,000 Hz from 8.0-10.5 seconds

7.0 Conclusions

As I stated above, Counterintuitively, I am not upset about not being able to analyze the data on a second to second time scale because I learned how drastically the oscillations can change in .5 seconds. It looks like the only ranges where extended oscillations are present are at; 60 Hz intervals up to 480 Hz, 1,740 Hz – 1,900 Hz, and 3,060 Hz – 3,240 Hz. The largest amplitudes exist at these vibration frequencies. If an experiment can survive that in testing and the 30g –
50g forces, then the mechanical systems should be safe in actual launch conditions.

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Because of the myriad of pitfalls this year, I was not able to fly the full experiment, so I am looking forward to the opportunity to fly the full system this upcoming year. Now that the physical construction is sound, all we must do is perfect the code and send it up one more time to have orientation data and acceleration data with the vibration data. The vibration data will also benefit from having directly fastened accelerometers, possibly providing even more clarity in the readings.

9.0 Benefits to the Scientific Community

Quite simply, knowing the vibration profile of the enclosure that will house an experiment provides close to exact inflight conditions. Replicating these conditions for testing might help prevent future experiment failure. This is a simple, but practical set of information.

10.0 Lessons Learned

This year I learned to test software beforehand so I am not scrambling to find a program to run a detailed analysis that can handle large amounts of data. I also learned how difficult and fun it is to design custom accelerometers. My team learned how to properly program and test a high-level system, as well as how to use UART. Walter learned how to quickly switch from C++ to Python and how to write code for complex electronics.
As a team, we learned how to adapt and succeed quickly to last minute errors and sizing issues. All are lessons we can add to our formidable knowledge base as we train the next students that come to learn and build experiments alongside us as we finish up our time at this college, allowing them to take the reigns and build whatever experiment they can think of that can give them a real challenge.

11.0 Appendices

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**BRCTC Space Team**

The experiment, designation BRCTC Vibe, is a vibration experiment that seeks to record vibrational data from the launch of the sounding rocket. Vibe data will be used to analyze Hertz data within the experiment enclosure throughout the flight.
From left to right

Students: Alberto Torres, Chris Sibole, Willis, David Wells, Walter Willis, Ronald Willis, Corey Hummer (not pictured), and Justin Shay (not pictured)

Advisor: Gervase Willis (pictured on the right)
1.0 Mission Statement

The goal of BRCTC Vibe is to successfully record an accurate vibration profile (Power Spectral Density or Frequency Analysis) of the canister in the rocket to provide vital hertz data to future Rocksat teams. We expect to record accurate, high resolution hertz data which will be presented on paper and in an animated VR environment.

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 of the vehicle. When this occurs in a mechanical system, sensitive electronics can de-calibrate and catastrophic damage can occur. We wish to keep future teams informed on what to expect from the enclosed environment to mitigate potential damage to experiments.

We wanted to design a pragmatic experiment with useful data. Many teams design high risk experiments with fantastic scientific research and well-made electronics. We thought it would be different and interesting to keep developing an experiment that can be immediately useful to NASA and future teams, while also being informative and a challenge for the team.
2.0 Mission Requirements and Description

This mission required key components for full mission success. We needed at least 1 gyroscope that could provide us with orientation and acceleration data, 3 single axis accelerometers, or both. All components with moving parts and sensing capabilities needed to be able to withstand up to 50g at the least. We also needed a main controller, a UART to communicate data, possibly an ADC, a RTC, and possibly an OP amps if we chose to use the piezoelectric discs from last year.
Analog to Digital Converter

Gyroscope
Accelerometers/piezos were required to sense mechanical oscillations, especially at a low price and with limited space. A gyroscope is 3 accelerometers, one for each axis, calculated to show orientation and acceleration, which is why we wanted a gyro on board. While the gyro is not a requirement, it provides data on in-flight conditions, so it increases the resolution of the experiment, which makes it an asset to the mission.

We required processing power that could record, store and communicate data simultaneously, so we decided from the conceptualization of the experiment to use a Raspberry pi 3B+. The RTC was used to keep track of time to notate changes in the sample rate over the course of the mission. This would allow me to compensate for irregularities in the sample rate caused by overhead load on the processor. There simply wasn’t enough space for multiple controllers and multiple save devices that are more typical with smaller single function
controllers. The surface area needed to be reducible if the main enclosure ended up having defects after fabrication.

3.0 Payload Design

I (Ronald) had a design in mind for this project since conceptualization. This project has been my brain child for 2 years now. The design is quite simple; a main board to house the ADC, RPi, RTC, Gyro, and UART. The 3 accelerometers would be fastened directly to the inside of the enclosure, one on each axis. Design progression:
Our original design is an improved design from last years’ experiment, incorporating a compact design in case we were required to shrink a little. We recorded usable data last year, so the design was already proven to work. The only aspects I wanted to improve upon were adding the ability to transmit data in case the rocket was lost and designing independent accelerometers, one for each
axis. After researching piezoelectric discs, we investigated how to create custom accelerometers.

![Diagram of custom accelerometer design]

Changed piezo holder to enclosed casing to hold piezo and add known mass

During our investigation, we found that a known mass and more calculation was required in constructing useful custom accelerometers. We also
learned there was a UART built into the RP 3B+, so we tested to see which was
easier to interface with, program, and send data with.

Switched to COTS accelerometers to save time, increase reliability and guarantee a
specified sensitivity and resolution.
System Overview: Software Design

Power on GSE-1
- Initialize threads
- Create file headers
- Handle exceptions and restart threads as necessary
- Threads lock on available processors
- Get data
- Send data to queues
- Create telemetry summaries

Telemetry Thread Ready
- Send data to base

Gather continuously
Early code

After a lot of research, we decided to off ramp the custom accelerometers to save time and use the UART built into the RP 3B+ because it was superior to the independent UART. During this time, I had realized there were discrepancies between what I had designed and was supposed to be integrated into the enclosure. After double checking sizes and designs, I requested enclosure information and discovered that the enclosure was designed with the incorrect dimensions, meaning our experiment had to be reduced in size.

After working with Jared and Ryan, I was given the size of the enclosure space and was able to match the dimensions given to them by the mechanical team at WVU. After designing and ordering a new set of boards and soldering components, I sent the experiment for testing. Unfortunately, the enclosure
details given to me were not accurate, so my new board needed to be cut for initial integration.

During the first integration, I traveled with My advisor to measure the enclosure myself to verify accurate measurements. After taking measurements and working with Jared and Ryan, we were able to accurately detail the enclosure space. Upon returning home, I got to work on the final revision of the experiment.
Final design to compensate for enclosure manufacturing error
The final design, seen above, was designed and sent for fabrication. There was not enough room for the ADIS Gyro, so I designed a new board to be placed next to the Z axis accelerometer and shortened the length of the main board. Unfortunately, the mechanical design team didn’t know how to fabricate the enclosure to include the fastened components, so they had to design a 3D printed holder for the accelerometers and the ADIS Gyro (I was informed of this after sending the final revision for final integration), which was adhered in place in the enclosure. The last-minute addition of the 3D holder also meant a reduction in space, so we had to off-ramp the ADIS Gyro this year. I had Walter remove it’s code from the larger body of code as a precaution. The accuracy of the readings was reduced by the 3D holder, but not by a large amount. The frequency of the wave form is distinct enough to easily be seen on the Z axis with little distortion.

Most of my design changes were more to overcome challenges for integration, rather than to suit the functionality of the experiment itself. It was a frustrating, but also useful challenge. Having the experience of changing an experiment last minute is vital experience for needing to solve issues on the fly in R&D prototyping, so I am happy for the experience.

Weight and power were well below what was available, so we did not have to worry about affecting other experiments.
<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All PCBs and ABS</td>
<td>53g</td>
</tr>
<tr>
<td>ADXL1001Z x3</td>
<td>7.5g</td>
</tr>
<tr>
<td>RTC</td>
<td>2g</td>
</tr>
<tr>
<td>Raspberry Pi 3B</td>
<td>42g</td>
</tr>
<tr>
<td>ADC Pi Hat</td>
<td>18.2g</td>
</tr>
<tr>
<td>ADIS 16460</td>
<td>15g</td>
</tr>
<tr>
<td>UART</td>
<td>4g</td>
</tr>
<tr>
<td>1/8 inch machine Screws x12</td>
<td>181.5g</td>
</tr>
<tr>
<td>1/4 in Machine Screws x6</td>
<td>105g</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>428.2g ~ 15 ounces</strong></td>
</tr>
<tr>
<td><strong>Over/Under</strong></td>
<td><strong>(1.00)</strong></td>
</tr>
</tbody>
</table>
4.0 Student Involvement

Ronald Willis – Team, Electrical, Mechanical, Design, and Fabrication Lead. Throughout the experiment, I checked all physical systems, approved them, and designed all but a few specific 3D models. We had teammates that had to leave, or focus on work, so I made sure everything except code was perfect.

Walter Willis – Code Lead. Walter wrote and designed all software for the project. His work was invaluable to the project.

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A member of the West Virginia Space Flight Design Challenge, the West Virginia University RockSat-X team is a collaboration between the Amateur Radio Club and Experimental Rocketry Club. Our flexible antenna aims to demonstrate methods of re-entry data deployment and transmission while conforming to form factors dictated by launch vehicles and payloads.
1.0 Mission Statement

The West Virginia University payload is a collaborative effort between the WVU Experimental Rocketry Club (WVUER) and the Amateur Radio Club (ARC). Both clubs are funded under the Statler College of Engineering and Mineral Resources. Totaling 18 students and our advisor, Dr. Piyush Mehta, the team has devised an experiment that tests the strength of radio signals through the atmosphere. To do this, the team utilized a custom-made deployable dipole antenna, set to deploy when the fairing is removed.

2.0 Mission Requirements and Description

In order to succeed, the mission had several requirements that needed to be met before a test launch could take place. For this to be achieved, the team was divided into several different sections; Electronics, Antenna Design, Antenna Deployment, and Flight Prediction. Each subteam leader that reported to one of the main mission officers. This division of power helped to ensure the team was constantly on top of all deadlines. Many of the mission requirements set by the team were independent of the RockSat-X program and was used to ensure the team would deliver a meaningful payload and get valuable results.

Our internal requirements included:

- Meeting all program presentation deadlines
- Conforming with all Wallops design constrictions
- Design, build, and test a morphing antenna
- Design, build, and test a PCB and transmitter
- Design, build, and test an antenna deployment system
- Integrate all sub systems into a working payload and test
- Present project to conference (IEEE)
- Integrate working payload into WV Collaboration
- Design code for real time landing zone and flight prediction

Minimum success criteria:
- Deployment of antenna
- Transmission of single data point

A picture of the Con-Ops has been provided below:
3.0 Payload Design

The design of the experiment is broken up into four sections: the antenna, the deployment system, the electronics, and the flight prediction. Even though each of these systems are distinct, each one relies on the other in order to properly work. This is laid out in the functional block diagram displayed below.

The antenna is the core of the experiment. Therefore, it has undergone the most change throughout the project. Immediately, a dipole antenna was decided as the best antenna model to pursue. This is because if the radial transmission it possesses and the simplicity of its design. It would also be easy to conform to the deck, with each of the antennas being bent back in a semi-circle along the circumference of the payload bay. The first obstacle was to design a housing to keep the wire that would act as the antenna rigid. Initially, the antenna was designed to be made of fiberglass, due to its lightweight nature and good elastic potential. However, the team soon realized that if the antenna was going to transmit in the atmosphere, then it would need to be able to withstand the temperatures of reentry. In order to accommodate for this, Kevlar was selected as the coating material, because it possesses similar properties to fiberglass but has a much higher heat tolerance. Next, the team needed to determine a band to transmit on. It was soon decided the
antenna would broadcast on the 900MHz band. This was because of its class as an amateur radio band, and one which several team members had experience using. Once all this was decided, the length of the antenna was set to 160 cm (6.3 inches) this was used to match the wavelength at the frequency being broadcasted at. In the end, several designs were made, tested, and tweaked before coming up with the final design pictured below.

When it comes to the deployment mechanism, the design criteria are simple. It needed to hold up the antenna stowed in place until the event at apogee, it needed to withstand vibrations, and it needed to deploy quickly. In order to accomplish this, the team decided on a stepper motor with a hinge. Stepper motors are excellent at holding a specified position due to the magnetic forces being used but are also quick to respond and can rotate quickly. Originally, a hinge was designed as the holding mechanism, but it was eventually scrapped instead for the cam mechanism. This was because the hinge had a torque acting against the shaft, which caused problems with the motors during vibrations and could cause the antenna to prematurely deploy. In the cam design, however, the antenna exerts a bending force on the shaft of the motor, which was proven to be more reliable and consistent with deployments. The motor mounts were designed to allow the stepper motors to slide inside, securing them firmly to the payload. Four bolts were then added to permanently fix them to these mounts.
The electronics had three major components; an Xbee, a Raspberry Pi, and a Navspark mini. Each of these components were selected because they were easily available, and members had experience using them. The Xbee functioned as the radio that would transmit the signal through the deployable antenna, while the Navspark was the GPS that collected location data that was meant to be fed to the prediction software. Finally, the Raspberry Pi was the computer on board and was supposed to control the different systems as well as run the prediction software. All these pieces were mapped out onto a PCB and assembled to fit within the size constraints given by the WV collaborative.

The final subsystem that was designed was the flight prediction software. This was coded fully in Matlab, and made use of trajectory modeling, numerical integration, and data analysis to predict where the landing site of the payload would be. It would start at launch, using the data provided by the Navspark to begin its prediction. Throughout the flight, it would use all the data collected to update the landing zone and construct a better flight path. Upon landing, this flight path would then be compared to the actual flight path to determine how accurate the final prediction was. A Monte Carlo Analysis was also carried out in order to account for variances in weather, density, and other atmospheric conditions. It was then supposed to be coded in C and uploaded to the Raspberry Pi. However, the C code never successfully ran, so this project was descoped after the Matlab modeling was finished. The final prediction it created is displayed below.
4.0 Student Involvement

Table 1: Student Name and Contribution List

<table>
<thead>
<tr>
<th>Student</th>
<th>Major</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graham McConnell</td>
<td>Mechanical &amp; Aerospace Engineering (MAE)</td>
<td>Principal investigator and Group 2 (MAE) lead of experiment. Updated CoSGC and IV&amp;V. Machined several parts and aided with final integration. Attended 2nd Wallops visit.</td>
</tr>
<tr>
<td>Mark Czerner</td>
<td>MAE</td>
<td>Antenna design subteam lead. Machined mold for antenna and assembled several iterations. Also aided in system integrations. Attended 2nd Wallops visit.</td>
</tr>
<tr>
<td>Matteo Cerasoli</td>
<td>MAE</td>
<td>Member of antenna subteam. Assembled various antenna prototypes and assisted in testing them. 3D printed several test parts. Attended 2nd Wallops visit.</td>
</tr>
<tr>
<td>Will Howard</td>
<td>Electrical Engineering (EE)</td>
<td>Project manager and Group 1 (EE) lead until graduation. Coordinated purchasing, worked with IV&amp;V, and updated CoSGC.</td>
</tr>
<tr>
<td>Name</td>
<td>Major</td>
<td>Role and Contributions</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Troy Pallay</td>
<td>EE</td>
<td>Electrical subteam lead until graduation. Worked on programming Xbee, wiring schematics, and Raspberry Pi on-board rocket.</td>
</tr>
<tr>
<td>Cae Gutierrez Quintanilla</td>
<td>MAE</td>
<td>Member of electronics subteam. Helped research electrical components and provide findings to team lead.</td>
</tr>
<tr>
<td>Jonathan Pulley</td>
<td>MAE</td>
<td>Was Integration and Deployment subteam lead. Helped develop antenna deployment mechanism and attended both Wallops visits.</td>
</tr>
<tr>
<td>Emily Certain</td>
<td>MAE</td>
<td>Served on Antenna team; supported the development and documentation efforts for fabricating deployable antennas to withstand harsh re-entry environment.</td>
</tr>
<tr>
<td>Nathan Musser</td>
<td>MAE</td>
<td>Researched materials including protective wire coverings, release mechanisms, and stepper motors to release the antenna. Designed the mount for antenna to secure to plate. Attended 1st Wallops visit.</td>
</tr>
<tr>
<td>Cicely Sharafati</td>
<td>MAE</td>
<td>Part of deployment and integration sub-team. Focused on gathering data on stepper motors for experiment. Attended 2nd Wallops visit.</td>
</tr>
<tr>
<td>Annette Straziuso</td>
<td>MAE</td>
<td>Part of deployment and integration team. Researched materials and background information.</td>
</tr>
<tr>
<td>Zachary Rahn</td>
<td>MAE</td>
<td>Subteam lead of flight prediction subteam. Designed Matlab code to iteratively predict landing zone of payload. Designed Monti Carlo analysis to better predict landing zone.</td>
</tr>
<tr>
<td>Thomas Nichols</td>
<td>Computer Science (CS)</td>
<td>Member of electrical subteam. Worked with electrical diagrams and programming of the Raspberry Pi.</td>
</tr>
<tr>
<td>Liam Thomas</td>
<td>MAE</td>
<td>Helped in fabricating and designing prototype antennas.</td>
</tr>
<tr>
<td>Jeffrey Moe</td>
<td>EE</td>
<td>Acted as testing director for team. Checked results of each subteam and worked to keep updated testing documentation.</td>
</tr>
<tr>
<td>Kendrick Chirino</td>
<td>MAE</td>
<td>Member of prediction subteam. Did background research of filters and orbits.</td>
</tr>
<tr>
<td>Matthew Fox</td>
<td>MAE</td>
<td>Worked with the antenna design team and did background research on cube-sat designs and deployment methods.</td>
</tr>
<tr>
<td>Cameron Hale</td>
<td>MAE</td>
<td>Part of electronics subteam. Selected XBEE antenna and frequency to be used to transmit on.</td>
</tr>
</tbody>
</table>
Our team was divided into two sections, an electrical group and a mechanical group. These two teams were then subdivided into four subteams. Each subteam had a leader who would report to the head of his respective group. In addition to this, the team had a designated testing director, who oversaw all the testing that occurred and kept a running log of all testing events and their outcomes. This hierarchy was designed to play to the strengths of both clubs in the collaborative, as well as better divide our large team and create more focused areas.

5.0 Testing Results
Several tests were conducted during the progression of the project. One of the major tests conducted was that of the antenna transmission, which was composed of two parts. The first was a trial antenna that was connected to a signal reader. Then, a team member would speak into a radio set to the same frequency. The signal reader would then output the signal and ensure the data received was comprehensible. The other test was to hook another prototype directly to a radio and attempt to communicate with it at the 900 MHz frequency. Both tests were deemed successful, and the antenna length was set. The only thing that the team changed after these tests were the size of the Kevlar housing to better fit within the payload.
Another test investigated testing vibrations. This was done by mounting the antenna and the motors to a piece of steel and stowing the antenna. Then, two students shook the assembly to see if a premature deployment would occur. As was stated above, the hinge failed this test, so it was scrapped for the cam design, which ended up keeping the antenna stowed.

Another fear was the antenna would not deploy if it was stowed for a long period of time. To test this, the team created a quick prototype and mounted the antenna onto a wooden board in a stowed state with screws. This was left undisturbed for two days. Upon completion of the second day, the screws were removed, and the antenna successfully return to its initial state. This proved that the deployment would be feasible and full-scale prototype assembly began soon after.
6.0 Mission Results

Upon arriving at the launch site, the first task for the team was to set up the ground station and try and receive a data transmission during the flight. In order to receive the strongest signal, the antenna needed to be continually pointed at the rocket throughout the flight. Therefore, one member watched the screen, while another aimed the antenna and tracked the rocket. Throughout the launch, no signal was found on the expected band. There was, however, a faint signal around 901.55 MHz. This signal is pictured below in figure 10.

Unfortunately, due to complications during splashdown, the team was unable to confirm whether this was due to our experiment or not. However, the team has concluded that this is unlikely due to its weak signal and distance from the expected frequency.

After the recovery of the payload, visual inspections were able to confirm several things about it. First, the antenna had been successfully deployed. The Kevlar antenna
wasn’t curved along the perimeter of the payload, nor was it restricted by the mechanical arms.

Figure 14: Post Launch Payload

In order to ensure the motors worked as intended and did not deploy the antenna during reentry, the steppers on deck were checked next. Upon further inspection, these were found to be in the deploy orientation, confirming that they had worked as intended and deployed after the removal of the fairing. Because of the nature of the motors, this orientation could not have been caused by forces during reentry.

Figure 15: Left Antenna Deployment Arm                             Figure 16: Right Antenna Deployment Arm

As for the antenna, the team found that one had successfully survived, while the other had delaminated during reentry. Although it isn’t possible to determine how far into reentry the epoxy failed, it can be assumed that the excessive heat caused the failure, as that was a weak point in the design.

Figure 17: Antenna Assembly
Upon further inspection, the left antenna was found to be bent near the root of the antenna and frayed at the far end. This most likely occurred during reentry and was caused by the high drag forces experienced in this zone.

After the launch, the WV collaboration was disassembled and divided between the participating teams. As the disassembly began, it was found that the gasket seal designed by the team had not been properly designed, and water had leaked into the system after splashdown. This was shown in figure 19 below. Because of this issue, our electronics were damaged, and the memory card data was corrupted which hindered much of our data analysis for the antenna transmission.

7.0 Conclusions

The minimum success criteria for the mission was stated to be the successful deployment of the antenna and the transmission of a single data point. After the analysis, the team cannot conclusively say that the mission successfully met these goals. Though the antenna did deploy, there is not concrete evidence that any transmission occurred.

Through the results that the team received, there were several important conclusions that can be drawn. The first of these is in the assembly and makeup of the antenna. The initial hypothesis that Kevlar would be able to survive the heart of reentry was proven correct, as evidenced by the payload remains. The shortcoming with this was instead the epoxy, which melted off during descent. In order to overcome
this, the team would need to use a higher temperature resistant adhesive. Another conclusion to be drawn is that an antenna can be flexibly deployed in the middle of a mission. This allows for the possibility of antennas that require little to no power to deploy, while being simpler and lighter than current mechanical versions, conforming to size and weight restrictions. Finally, it was found that stepper motors were able to withstand the vibrations that are undergone within a rocket, hold an antenna in place, and deploy it once a fairing is removed.

Even with the shortcomings of our experiment, the results of the experiment are useful and can be helpful to teams who decide to pursue similar endeavors.

8.0 Potential Follow-on Work (0.5 to 1 page)

The payload was designed from the inception to be able to be built upon for future missions. The breakup of this mission had several components that could be followed up upon, including the deployable antenna, flight prediction, and data transmission.

With the rising popularity of CubeSats, deployable antennas are becoming more common than ever before. Any number of things could be researched in this field, whether it is a different design for an expandable antenna or ways to expand upon the design outlined in this report. One design the team scrapped that could be pursued further is an inflatable antenna. As for updating the current design, future experimenters could investigate higher temperature epoxy to determine if that was the critical factor in the antenna delamination. They could also experiment with several sizes or transmission bands to determine if it plays a factor in the strength of the signal received. As for data transmission, teams would attempt to transmit different kinds of data to try and determine what packets are received most complete, and which should be avoided. Finally, future teams could work to code a flight prediction system that could be integrated onto the payload, that could actively predict where the landing zone would be and how long before it reached the ground. It could also record other data on board, allowing the team to sync data with real time flight events.

9.0 Benefits to the Scientific Community (0.5 to 1 page)

Antennas are crucial for most experimental payloads, because it acts as the only form of communication between the ground station and the experiment. WVU’s antenna was designed to be lightweight and morphing in order to fit the criteria necessary for these space missions. This morphing aspect allows for the antenna to fit within a launch form factor, then expand beyond that once deployed. This can allow for larger antenna arrays, which are able to broadcast and receive stronger signals. Beyond this, many of the current morphing antennas rely on electro-mechanical systems to expand these arrays. This antenna, however, uses a passive, stored energy system, allowing it to spring out when the restraints are removed. This reduces the power required for the subsystem and reduces the points of failure from that of a mechanical system. Finally, the prediction system that was designed by the team and the analysis used to determine its accuracy has a variety
of uses as well. The applications of it with respect to control systems alone could benefit fields ranging from the defense industry to commercial videography drones. Though the results of the experiment were eventually inconclusive, they are still able to benefit science and progress current research, as well as inspire future research.

10.0 Lessons Learned

Throughout this experience, there are several lessons that have been learned. One thing that this team found useful was creating well devised teams that had specific tasks at hand. However, these specializations also led to a breakdown in communication between the teams. There were several occasions where one team would design their system around outdated information, which would cause delays once the problem was realized. The team eventually remedied this by having mandatory lead meetings every week, where the seven leads would discuss the progress that had been made and what the next steps were. Another lesson learned was that there is a possibility for material to be backordered, which can cause delays when working to assemble the model. A remedy for this would have been to order parts weeks ahead of time, so that there is time to retrieve them somewhere else if need be. Another lesson learned was to check the gaskets that protect the electronics in advance. Had that occurred, the team may have been able to conclusively determine whether the antenna transmitted or not. Finally, the most important lesson that was learned is not to procrastinate. Creating a Gantt chart and sticking to it is the best way to complete a project on time. This was difficult at times, especially when juggling schoolwork, jobs, and other extracurricular activities, but is essential to prevent burnout from members being forced to pull all-nighters to meet deadlines. Overall, as long as the team keeps up with the project and tries their best to communicate effectively, then the project should come together just fine.