West Virginia Space Collaboration
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West Virginia Wesleyan College
Fairmont State University
Blue Ridge Community & Technical College
Bridge Valley Community & Technical College
NASA Independent Verification & Validation Facility

July 19th 2017
1.0 Mission Statement

The primary mission of the West Virginia Collaboration this year was to embark on a collaborative effort with academic institutions across the state of West Virginia for development of knowledge and practical experience in designing, building, launching, and operating space payloads through NASA’s Space Flight Design Challenge Initiative.

The Space Flight Design Challenge is a program in which students and mentors can actively participate in the design & build phases of their own scientific payload. Provided the team is awarded a flight, each payload will be integrated into an experiment canister and launched on a suborbital sounding rocket out of Wallops Flight Facility at the close of the academic school year. The fall semester is mainly comprised of engaging students in the full design & review process whilst the primary goal of spring semester is to prepare each team to build and assemble their payload. In order to do so successfully, each of the payload will undergo multiple phases of testing and integration to ensure its suitability for flight.

In an effort to provide students with the stepping stones necessary to carry out the goals of the Space Flight Design Challenge, academic institutions are provided with the opportunity to gain hands-on experience through RockSat-C, an initiative aimed towards engaging students to successfully build and test space flight systems. As a result, students will be equipped with the skillset to fabricate and operate their own space flight systems in Low Earth Orbit through amateur radio operations.

This program is largely possibly due to the continuous support by both NASA Independent Verification & Validation and the West Virginia Space Grant Consortium.

This year West Virginia University, West Virginia Wesleyan College, Fairmont State University, Blue Ridge Community & Technical College, & Bridge Valley Community & Technical College all were awarded a flight in the WV SPACE Canister due to their elaborate display of scientific merit.

The first objective of our canister was to capture and store real-time flight data to show the flight path of the rocket. Each experiment on board implemented an IMU into their payload to capture redundant points of telemetry to later compare to the data received by Wallops from the flight. This objective allows our team to develop COTS orientation estimation techniques and provide a baseline experiment for new teams joining the program. This aspect of the mission was spearheaded by the Fairmont State University & Bluefield State College.

The second objective of our canister was to conduct a stress test of materials in space of several tensile samples. The objective was fulfilled by the Bridge Valley Community and Technical College team through the use of strain gauges and load cell amplifiers. To calculate the bending stress experienced by the samples, the BVCTC utilized the following equation:

\[
\text{Stress: } \sigma = \frac{F}{A} \quad \text{Bending stress: } \sigma_b = \frac{Mc}{I_{bending\ stress}}
\]
The third objective was to Measure the energy being generated by the rocket’s vibrations using piezoelectric generators. Both the Blue Ridge Community & Technical College team and the West Virginia Wesleyan team utilized the below equations surrounding piezo-electrics to quantify the energy produced throughout the flight.

\[
\{S\} = [S^E]\{T\} + [d]\{E\}
\]

\[
\{D\} = [d]^T\{T\} + [\varepsilon]^T\{E\}
\]

Where:
S= Strain
E= Electric Field Strength
T= Stress
d= Matric for the direct piezoelectric effect
D= Electric Charge Density
\varepsilon=Permittivity

Our fourth and final objective was to measure the plasma density in the upper atmosphere through the use of a Langmuir probe. The method works by inserting an electrode (LP) into a plasma, sweeping potential until the excitation voltage is observed; the measured currents and potentials allow the determination of the physical properties of the plasma. This experiment was taken on by the West Virginia University team.

Overall, these payloads allow us to benefit the small sat community by means of developing COTS orientation estimation techniques, proving the durability of sample materials in space to then be compared to manufacturer mechanical properties, and develop an understanding of the amount of energy given off by the rocket during flight.

2.0 Mission Requirements and Description

In order to fulfil our mission objectives, first several requirements must be met. These requirements are both made up of individual team requirements & guidelines set forth by Wallops Flight Facility. Wallops’ guidelines include:

The mission trajectory should cover a part of the upper atmosphere above 60 km and spend at least 2 minutes above 60 km.

a. The payload should fit in the provided volume defined by the half canister specifications outlined in the user guide. 9” in diameter and approximately 4.5” height).
b. Since power is not provided by the rocket we must utilize batteries to power the payload throughout the flight. Per the RockSat-C User’s Guide, lithium-ion cells may be charged on site; thus the power is to be supplied by disposable lithium batteries. Our canister doesn’t anticipate the use of high-voltage sources other than that contained within the Geiger counter device.

c. The payload must be electrically isolated from the canister.

d. An optical port is required for the cameras.

In accordance with our individual WV SPACE canister, each university team was required to comply with the following design specifications:

a. A data collection system is required to store the measurements (in-flight).
   a. The acquisition rate should be 10 Hz or higher.
   b. Flight dynamics & magnetic field data must be collected throughout entire flight.
   c. Payloads should fit within a 4”x4”x1.5” volume to comply with CubeSat design constraints.
   d. Payloads shall be provided 3.7V – 4.2V input voltage.
   e. Magnetic field: the field should be measured at an accuracy of 100 nano Tesla.
   f. Geiger counter: energized particle (cosmic ray) detection must occur from 60km to apogee.
   g. Redundancy should be built into the payload for flight dynamics comparisons.
   h. For power, each payload was required to incorporate the same 4-pin connector supplied by Digi-Key.

All together, these requirements allowed each of our 6 participating schools to work remotely on the same payload before the final integration at the FMSR.

The WV SPACE Collaboration 2017 payload is comprised of 10 subsystems (Figure 1). These Experiments include:

1. WVU-VID: The West Virginia University VID Experiment captures visual telemetry of payload devices in the form video using 1 standard USB Pi camera.
2. WVU-LP: The West Virginia University Langmuir Probe experiment sweeps the voltage bias on a conductive probe mounted on the exterior of the rocket in order to determine characteristics of plasma in the upper atmosphere.
3. WVWC-HE: The West Virginia Wesleyan College Harvest Energy experiment focuses on measuring the energy produced by the rocket throughout the flight via piezo-electric crystals. The payload also possesses an IMU to record accurate telemetry data to be compared to the data given by Wallops.
4. BRCTC-PiGen: The Blue Ridge Community & Technical College PiGen experiment focused on measuring the output of 3 piezoelectric generators on the X Y and Z axis with an oscilloscope, while charging three separate batteries with no attached load. An array of sensors will be used to track the trajectory of the rocket throughout the
launch and vibrations will be recorded to match voltage being generated by the piezoelectric generators. A 3D printed enclosure was designed to isolate this experiment from the rest of the payload.

5. FSU-FDA: The Fairmont State University SPACE experiment focused on flight dynamics comparison to map the trajectory of the flight to then be uploaded to their flight dynamics application.

6. BSC-VIMAT: The Bluefield State College experiment included the procurement of real-time flight data to be stored to an SD card – This data was then to be used to determine flight path, trajectory, altitude, and rotation of the rocket. A 3D printed enclosure was designed to isolate this experiment from the rest of the payload.

7. BVCTC-SG: This Bridge Valley Community & Technical College SPACE experiment focused on modeling flight path and a conduct a stress analysis of tensile samples in space.

Three other structural/operational subsystems include:

8. Power distribution system (PDS). The unregulated 7.4V LiPo battery power supply is controlled and regulated on a dedicated board to 5V and 4V. Power is distributed to each experimental subsystem as required with individual circuit breakers in case of a power surge or short circuit. This subsystem possessed the ability to detect (in real time) and shorts or power failures that occur during the flight to be recorded on an SD card for later analysis.

9. Multipurpose Port System (MPS). The circuit board mounted inside the multipurpose port housing for exterior sensors.

10. Structural Integration System (SIS). The main mounting plates, mounting hardware, camera mounts, and ballasts all comprise this subsystem.

The system block diagrams show the 10 subsystems and their interconnections in Figure 1. The blue line indicates a control signal. The yellow line is a 7.4V power line used for the linear actuator, the red is a 3.7V power line for SPACE experiments, and red line is an 5V power line for Raspberry Pis.
3.0 Payload Design

The following section discusses how the individual payloads and subsystems were designed in accordance to the user guide. An overall model of the WV SPACE Collaboration RSC-2017 assembly can be seen in Figure 2. There are two sections that make up the half canister payload. The upper section contains the WVWC-HE experiment and the WVU-LP Data Acquisition Board along with the Power distribution board. The lower section contains WVU-VID, BRCTC-PiGen, FSU-FDA, BSC-VIMAT, and the BVCTC-SG experiment. Additionally the lower section housed all of the ballasts required to meet the weight requirements set forth by Wallops. The ballasts were applied strategically to ensure that our center of gravity remained in the center of our half canister. The ballasts used for this payload were $\frac{1}{4}$ oz. iron wheel weights with self-adhesive backing.
1. WVU-VID

West Virginia University 2 experiments in the RockSat 2017 payload canister. The first of these experiments was the WVU-VID experiment. The objective of this experiment was to capture visual telemetry of payload devices in the form video using 1 standard USB Pi camera. A Raspberry Pi camera was determined to provide adequate video resolution to provide quality video back from the flight – A fish eye lens was then coupled up with the pre-existing lens to allow more of the payload to be within view.

![Figure 2: Mechanical Model of Payload Assembly – Roger Targosky](image)

![Figure 3: WVU-VID Subsystem Block Diagram](image)
Design
This experiment incorporated all COTS components and no custom PCB designs were necessary. The Pi-Cam used a ribbon cable connection and a custom made connector to communicate with the PDB.

Figure 3: VID Camera with Raspberry Pi

2. WVU-LP

This was the second experiment flown by West Virginia University. The objective of this experiment was to:

- Measure the current induced on a Langmuir probe immersed in plasma within the upper atmosphere
- Measure longitudinal acceleration of the rocket (z-axis)

The system block diagram can be seen in Figure 4.

Figure 4: WVU-LP System Block Diagram
**Design.**

The Langmuir probe (LP) on the WVU-LP experiment will be used to determine electron/ion temperature, electron/ion density, and plasma potential of plasma. The method works by inserting an electrode (LP) into a plasma, establishing an electric potential between the electrode and surrounding vessel. The measured currents and potentials allow the determination of the physical properties of the plasma.

The LP is actually mounted within the multipurpose port on the MPS board along with some trans-impedance amplifiers and the WVWC Thermocouple wire. The I2C bus is also routed through the LP-DAQ board because an I2C buffer/line driver is included on the board.

![Figure 5: Mechanical Model of the WVU-LP DAQ Board](image)

**Data acquisition.**

The sensors used to collect the data were a single axis accelerometer with a 0-50g range to measure the maximum acceleration of the rocket and a 4” long stainless steel rod used as a Langmuir probe to measure electron temperature and concentration. A trans-impedance amplifier circuit was implemented in the DAQ board to record the necessary current measurements. A Net burner NANO54415 core module microcontroller was used to collect the data which was then recorded on a microSD card [11]. SDHC µSD card based storage. A 16-bit TI DAC8560 SPI DAC using internal 2.5V reference was implemented for the accelerometer. An 18-bit TI ADS8881 differential SPI ADC using external 4.5V reference was implemented in the DAQ board for the Langmuir probe trans-impedance voltages. The WVU-LP DAQ board also utilizes a TI TIPD115 reference design and prefabricated PCB to cut down on cost and complexity of the DAQ board.

3. WVWC-SPACE

The West Virginia Wesleyan College team designed their RockSat-C 2017 payload to:
• Measure flight dynamics through entire flight
  Measure the energy produced by the rocket throughout the flight through the use of piezo-electric crystals

The mission for WVWC-HE was to use an IMU unit to measure and react to the attitude, and change in attitude, of a rocket. The sensor components used to collect this data were a 10 Degree of Freedom (DOF) IMU and an openLog microSD card logger for data storage. This IMU is a heritage component that has flown on previous RockSat suborbital launches and proven to be fairly accurate and reliable. A subsystem block diagram of the WVWC-HE experiment is shown in Figure 6.

![Subsystem Block Diagram for WVWC-HE](image)

**Design**

All sensors were calibrated according to the procedures specified in the respective datasheets. A PCB was designed and ordered from the Advanced Circuits vendor. A 5V regulator was incorporated to power the microcontroller and the other devices. A mechanical model of the WVWC-HE PCB assembly is shown in Figure 7. The electrical schematic and PCB design is included in the Appendices.
Data acquisition.
The 10 DOF Adafruit IMU provide known temperature and motion measurements to compare to thermocouple and piezo data.

The microcontroller used to operate this experiment was an Arduino Pro Micro. This microcontroller was selected due to its low cost, very small footprint size, and because of the relatively simplistic C++ programming offered by the Arduino environment; the team found that this was a better choice compared to the Arduino mini used the year before. The open source nature of the Arduino software also promotes a vast online source of tutorial, technical, and troubleshooting information as a valuable resource. A 16GB micro SD card was once again used in the open Log device as the choice for data storage since it would provide plenty of space for data acquisition through the flight.

4. BSC-VIMAT

The Bluefield State College designed their payload in accordance to the Space Flight Design Challenge baseline payload for new teams as seen in Figure 8. This experiment included the MPU-9250 as their IMU of choice due to its capability to record data the entire flight. The micro controller of choice was the Arduino pro micro due to the team’s familiarity with the component and the low cost. Instead of using a traditional PCB, the team decided to utilize a breadboard instead for their payload due to the feasibility.
Sensors x (y)-axis of the accelerometer is aligned with the y (x)-axis of the magnetometer; the magnetometer z-axis (+ down) is opposite to z-axis (+ up) of accelerometer and gyro! We have to make some allowance for this Orientation mismatch in feeding the output to the quaternion filter. For the MPU-9250, we have chosen a magnetic rotation that keeps the sensor forward along the x-axis just like in the LSM9DS0 sensor. This rotation can be modified to allow any convenient orientation convention. This is ok by aircraft orientation standards.

**Figure 2: Subsystem Block Diagram for BSC-VIMAT**

Using these settings the filter is updating at a 145 Hz rate using the Madgwick scheme and 200 Hz using the Mahony scheme even though the display refreshes at only 2 Hz. The filter update rate is determined mostly by the mathematical steps in the respective algorithms, the processor speed (8 MHz for the 3.3V Pro Mini), and the magnetometer ODR: an ODR of 10 Hz for the magnetometer produce the above rates, maximum magnetometer ODR of 100 Hz produces filter update rates of 36 - 145 and 38 Hz for the Madgwick and Mahony schemes, respectively. This is presumably because the magnetometer read takes longer than the gyro or accelerometer reads. This filter update rate should be fast enough to maintain accurate platform orientation for stabilization control of a fast-moving robot or quadcopter. Compare to the update rate of 200 Hz.

**Figure 3: Mechanical Model for the BSC-VIMAT Proto-board Assembly**
produced by the on-board Digital Motion Processor of Invensense's MPU6050 6 DoF and MPU9150 9DoF sensors.

5. FSU-FDA

The Fairmont State University team designed their RockSat-C 2017 to recreate the flight of the rocket using flight dynamics and plot data into an app made by the CS department.

The FSU-FDA experiment is based on an accelerometers, MPU-9250 IMU, and a Teensy microcontroller unit. A subsystem block diagram for the FSU-FDA experiment is illustrated in Figure 1010.

![Figure 4: Subsystem Block Diagram for FSU-SPACE](image)

**Design:**
A PCB was designed to fit the individual design requirements using EAGLE and ordered from the Advanced Circuits PCB vendor. A voltage regulator circuit was incorporated into the PCB design to step up the 4V input voltage from the power distribution board to 5V for the Arduino microcontroller, accelerometers, the Teensy IMU, and open Log device. Figure 5 shows the physical model for the FSU-FDA PCB assembly. An electrical schematic for this PCB is included in the Appendices.
Data acquisition.

The microcontroller used in the FSU-SPACE experiment was the Teensy. This microcontroller was selected due to its low cost, very small footprint size, and because it was found to be more user friendly compared to the microcontroller used the year prior. A 16GB class 10 microSD card was used in the openLog device as the data storage solution since this was determined to provide plenty of space for data acquisition with the large flight duration 6.

6. BRCTC-PiGen

The Blue Ridge CTC team’s payload was designed to measure the output of 3 piezoelectric generators on the X Y and Z axis with an oscilloscope, while charging three separate batteries with no attached load. An array of sensors will be used to track the trajectory of the rocket throughout the launch and vibrations will be recorded to match voltage being generated by the piezoelectric generators.

The BRCTC-PiGen experiment is comprised of 3 Piezoelectric generators, 3 “button” batteries, 1 Adafruit 10 DOF, ADIS Gyroscope, Raspberry Pi, 3 Oscilloscope circuits, Vibration Sensor, and independent Accelerometer. A subsystem block diagram for the BRCTC-PiGen experiment is illustrated in Figure 6.
The main microcontroller was a Raspberry Pi. This was used in conjunction with a Magnetometer, Accelerometer, and 10 DOF & Vibration Sensors. PiGen will be a single PCB with all the sensors and the Raspberry Pi attached to it. The PCB will be mounted inside of an ABS 3D printed case. Major technology dependencies include that of: the Piezo transducers need to produce voltage, the vibration sensor(s) need to give precise Hertz measurements, the ADC must work through the Multiplexer to transfer the signals efficiently, and the LEDs must burn off excess power if needed.

The BRCTC team decided that a 3D printed enclosure for their payload would be useful to reduce the risk of any other part inside the canister coming in contact with the experiment, or any part of the experiment coming loose and contacting another experiment. This enclosure was designed to fit the exact outer dimensions of the PCB and incorporated notch cutouts to secure the board in place. An upper and lower section of the enclosure was designed to fit on the top and bottom of the PCB in a sandwiched fashion. An opening was also incorporated in the box to access the microSD cards and to provide power to the board.
Data acquisition.

- A Master program will be initiated on Pi startup. It will instantiate the RTC and set the system time. The System time will then be used to timestamp all device readings.
- It will instantiate all other devices and launch three sub-threads. The sub-systems are organized as follows:
  - 10DOF
  - ADIS16305
  - Accelerometer (ADC 2)
  - Piezos (ADC 1)

7. BVCTC-SG

The Bridge Valley CTC team designed their payload to measure the strain produced on a series of material samples and model flight path of the rocket.

The BVCTC-SPACE experiment is based on a combination of the analog devices Razor IMU and the Adafruit 10 DOF IMU. An Arduino Mini microcontroller was used for the data collection and the strain gauge configuration included a Wheatstone bridge and amplifier. A subsystem block diagram for the BVCTC-SG experiment is illustrated in Figure 8.
Design:

The BVCTC Payload is made up of 3 different subsystems. The Data Logging subsystem – Open Log SD Logger and the Spark fun Pro Micro. The Strain Gauge subsystem – 3 HX711 Load cell amplifiers, 3 tensile specimens (Aluminum, Polycarbonate, ABS Plastic) and 12 Omega Strain Gauges (4 per sample). 2 of 3 Samples and Sample Supports will be 3d-printed from various materials (PC-Plus filament survived Rocksat-2016 mission) and the samples are interchangeable; Wheatstone bridge wires will be connected via locking connectors similar to power connection. Flight Data Subsystem – Adafruit 10 DOF IMU & the spark fun Razor IMU.
Data acquisition.
The Arduino Mini 05 was replaced by the Arduino Pro Micro to reduce the overall footprint size requirement for the housing. The Arduino microcontroller was selected due to its low cost, very small footprint size, and because of the relatively simplistic C++ programming offered by the Arduino environment. Also, the open source nature of the Arduino software promotes a vast online source of tutorial, technical, and troubleshooting information. Finally, the Arduino Pro Micro has an adequate number of analog and digital I/O pins to interface with all sensors used in this experiment. A 16GB class 10 microSD card was used in the openLog device as the data storage solution since this was determined to provide plenty of space for data acquisition with the large flight margin. All data was recorded at a rate of 10 Hz.

In addition to the seven experiment subsystems, two other subsystems were used:

8. Power Distribution System (PDS)
The main objective of this subsystem was to regulate constant voltage to each of the experimental subsystems while providing isolated over-current protection for each regulated voltage line. LED indicators were incorporated to provide visual telemetry of the lines which were powered or “hot”. If any one line draws more than 800mA, a circuit breaker will blow and the LED will no longer emit light as current will no longer be supplied to that voltage line. This prevents the single 4V regulator that is supplying power to each SPACE experiment from experiencing an over-current and getting damaged. This would cause a loss of power for each experiment and a loss of mission for the SPACE payloads. These 5V regulators are also current protected with a circuit breaker to prevent damage to electrical components.

A power budget for the RockSat-C 2017 mission is shown in Table 1 for all experiments. The payloads all have a maximum current draw of 700 mA, but most of them actually do not draw this much since it would blow the circuit breaker. However,
this value was used in power budget considerations to build in an inherent cushion. A total flight margin of 1.3 was calculated and determined to be sufficient using two 7.4V @ 5000mAh LiPo batteries.

<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>WVWC-SPACE</td>
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<td>0.80</td>
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Table 1: Power Budget for the RSC2016 Mission

9. Structural Integration System

The objective of the structural integration system was to satisfy the requirement of providing structural support for all experiments, rigid camera mounts, and ballasts to meet the weight requirements. Structural support was achieved with two custom machined Makrolon polycarbonate plates, polycarbonate camera mount, and aluminum standoffs and hex bolts. Strips of ¼ oz. iron wheel weights were used as ballasts since they had their own self-adhesive made for high-vibration environments and long-lasting durability. These strips could also fit in fine spaces, could be cut at varying length and stacked together, and could be used for fine-tuned weight adjustments. A significant amount of weight was required to make up the total ballast weight which was over 5 pounds. Table 2 shows final mass budget for the RSC2017 payload.
### Table 2: Mass Budget for the RSC2017 Mission

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<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Total Mass (lb)</th>
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<tr>
<td>WVWC-SPACE</td>
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<tr>
<td></td>
<td>Sensors/DAQ</td>
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<td>PCB</td>
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<tr>
<td></td>
<td>Sensors/DAQ</td>
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<td>PCB/Housing</td>
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</tr>
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</table>

# of Ballasts TBD after OSU integration

## 4.0 Student Involvement

As mentioned in the Mission Statement, students from all across West Virginia have designed and built experiments on this payload. At WVU, Emily Certain designed & coded and built this year’s VID experiment. Greg Lusk, a WVU researcher, designed and built the WVU-LP experiment while Matt Gramlich provided C++ software support and assisted in testing. Lusk also designed and built the Power Distribution System. Both Matt and Greg also provided technical support for each team as problems arose and assisted in testing the fully integrated canister.

For West Virginia Wesleyan College’s experiment, Team lead Angela Meyer and Electrical lead Olivia Rycroft designed, built, and tested their Harvest Energy experiment. Angela did a phenomenal job at providing adequate document deliverables to represent the WVWC team.

For the Fairmont State team, Isaac Lambert was the team lead that made sure all project deliverables were submitted on time. David Klug provided software support and PCB design and testing while Jeff Reynolds also helped with testing and communication. Mickey Barry provided exceptional technical support to the FDA experiment and Derek
Barnett did an exceptional job at representing the team during each milestone presentation.

For the Blue Ridge CTC Team Ronald Willis was the project lead. Ron did an incredible job at preparing his team for what was ahead of them and always took initiative to help other teams in need. Walter Willis provided exceptional software support that went above and beyond; David Wells served as a mechanical lead to ensure that the payload was structurally sound, and Jerimiah Rahilly assisted Walter Willis in the area of software support for the payload.

The Bridge Valley CTC was led by Jonathan Stollings and also supported by Julie Settle early in the year. Jonathan contributed largely to the success of the team and was once again the last one left standing by the end of the semester despite the fact that he graduated during the fall semester. Jonathan performed exceptionally and displayed a vast amount of scientific merit that translated to the rest of the canister. Lastly, the Bluefield State College team was our one new comer for thing year’s WV Collaboration Payload. From start to finish, the team displayed a significant amount of effort that was prevalent in each milestone review, presentations that outlined their understanding of their payload, and through the experiment itself. The effort was led by Logan Spencer as the team lead and largely supported by Brian Sanders as well. The testing rigs for vibe and g loading was extremely impressive.

An organizational team breakdown chart can be seen in Figure 10.
5.0 Testing Results

Each payload was tested in several different ways prior to the FMSR integration event. The majority of the testing took place in facilities housed by each participating institution. The IMUs and magnetometers were tested using a variety of vibration rigs, testing onboard Cessna Aircrafts, and the Bluefield team fabricated their own G-loading rig the test their payload in each axis. The VID experiment was tested to ensure adequate lighting and audio coverage while inside the experiment canister to be run for the full duration of the flight.

During at-home day in the life testing, there some issues that arose that were common across each team. It was decided that all micro SD cards will be staked into the sockets using a small dab of silicon RTV due to the fact that some teams found that their SD card was coming loose and not collecting data during simulated tests.

Finally, spin and vibration testing were performed during the integration week at Wallops. All experiments were powered on for these tests, though at the conclusion of the tests the power distribution board indicated that there was a short that occurred during the vibe test. This short would later prove to be detrimental to the success of the WV Space Collaboration.

6.0 Mission Results & Conclusions

The Terrier-Improved Orion launched at approximately 05:30 am on June 22, 2017.

Debrief:

During the flight the West Virginia Collaboration payload did not receive adequate power for the mission. During vibration testing (6/16), the ballasts adhered to the underside of the top plate broke loose and ended up rattling throughout the canister. That weekend teams continued to work on their payloads & Sunday night (6/18) it was identified that power was not being distributed properly to each board; the issue at hand was then researched for points of failure. Though the team worked tirelessly with Oregon Tech on (6/20) to develop a new proto-board to replace the original power distribution board, it ceased to operate during flight (6/22).

Given the circumstances, I am extremely proud of how well each team responded to these results and was able to take much from the experience alone rather than just the data. In my time of leave for a funeral from (6/15-6/19) I received an overwhelming amount of support from students willing to step up in my place and I couldn’t be more thankful.

Overall, despite the results, each team was incredible thankful for the valuable opportunity to be involved in the WV-SPACE collaboration and awarded flight through RockSat-C.
8.0 Benefits to the Scientific Community

The anticipated benefits of the WV-Collaboration payload was made up of 3 different action items. The first was to develop COTS orientation estimation techniques to aid in the design phase of future missions. The second objective was to prove durability of sample materials and compare to manufacturer mechanical properties. The final goal was to aid in the development and understanding of the amount of energy given off by the rocket during a suborbital flight.

9.0 Lessons Learned

Several lessons were learned during preparation for this mission. Software development was done early in the spring semester and then revised a few times, but it is important to test it frequently, similar to the electronics and sensors. Accurate and timely communications between team members are important to avoid misunderstandings that create further delays. Communication platforms such as Slack proved to be a superior change up in the way that the team was able to remain cohesive. Each team found that it was more convenient to utilize its dual functionality to both share files and message one another. A few weeks into it initial implementation, a “team collaboration: channel was added that created breakthrough solutions in that all of the teams were finally able to work together despite the distance of their academic institutions.

Finally, PCB design software should be selected in the fall semester to allow for electrical schematics to be created prior to winter break. PCB designs should be finalized in the late February timeframe and the 1st round of designs should be fabricated by early March. Always plan on doing at least 2 rounds of PCB designs!

After our fallout, it was determined that it would be most sufficient to have a Power Distribution board back up in case vibe testing doesn’t go as planned.

10.0 Potential Follow-on Work

Now that each of the participating schools of the RockSat-C 2017 WV Collaboration launch has the experience of putting together a basic payload for suborbital flight, there is a high probability that each team will either design new payload for 2018, or modify their existing payload and fly again in 2018 to test its functionality.

Acknowledgments: A special thanks goes to RockSat manager Leina Hutchinson for all her help coordinating such a great opportunity for the participating schools of the WV Collaboration! Despite the tremendous difficulties associated with running such a large team, Leina was always patient, understanding, and was great at keeping us on track. We also want to give a special thanks to Chris Koehler for creating such an incredible program in which we can all achieve the unimaginable-we can’t wait to join again next year! Another big thanks goes to the NASA IV&V Program for providing financial support and technical support to this effort alongside the West Virginia Space Grant Consortium who has been a strong advocate of this program from the very beginning!
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11.0 Appendices

Fig. 1: Ideal I-V Curve of Langmuir Probe [3]

Fig. 2: Mission Concept of Operations Diagram
Fig. 3 Final Mechanical Model of Full Canister Payload

**Materials & Placement**

- 16 PCB standoffs: 5/32” long each
  - 12 for the Space boards and 4 for the VID experiment
  - Each of these will need a 13/32” long screw to attach to the plates.
    - They are 6-32 screws
    - (1 pack of 100 92949A146)
    - 9 more standoffs: 4 for the LP DAQ and 5 for the PDB (9 of 91780A420)
- 8 Space Stack separators: 1.25” long each
  - 8 of 91780A335
- 4 spacers for the plate: ¼” each
  - 1 pack of 100 94639A706
- 4 posts to separate the lower section from the upper: 2.78125” long.
  - That’s the (1.25x2)+(1/16(for the PCBs)x2)+5/32(for the standoffs)
  - 4 of 93505A009
  - 4 of 91780A123