The primary mission is to design a complex, multi-experiment payload emulating the methodology of a satellite or other space vehicle. Mission success will be defined as all systems and modular payloads functioning and collecting data.

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1.0 Mission Statement

Our primary mission for this project was to design and construct a modular payload system emulating the methodology of modern satellites. This would allow for plug and play style functionality, streamlining the process of integrating student experiments for this year as well as in the future.

Part of this modular system would provide pre-configured data lines, power sources, and secure spaces for student experiments. The data line was to run through the center shaft to a centralized storage module; This could serve as the primary data storage for the experiment or as backup. For this project, all the experiments had their own local storage and used the data management system (DMS) as a secure backup.

Another critical piece of the modular design was to provide isolation to the modular bays. This way, if any modules or modules failed for any reason, none of the other modules would be adversely affected. This was an improvement upon past experiments, in which small errors became fatal to the entire payload. Each module was given its own power regulator board and fuse, along with a separate USB connection to the DMS, which was programmed with robust error handling to respond to failures and disconnections.

Our secondary mission was to improve upon a 2017 RockOn! experiment by measuring the differences in radiation between four Geiger-Muller tubes encased in different types of shielding materials. We hoped to discover what low-cost materials could be used as effective shielding for equipment and humans in space flight.

2.0 Mission Requirements and Description

The mission requirements were determined by a primary and a secondary goal. These goals briefly describe our overall project.

Primary Goal: Create a universal mounting system for student capstone projects that would benefit from hostile environment testing. This modular system will help maximize the availability of functional experiments within the payload volume.

Secondary Goal: Use Geiger-Muller tubes to determine the effectiveness of various types of radiation shielding.

The mission we assumed was to design a complex, multi-experiment payload emulating (downscaled) the methodology of a satellite or other space vehicle. Some of our main subsystems initially focused on attempting to quantify the effect of radiation upon complex electronic systems (FPGAs) at varying distances from the surface of the Earth. Our payload also integrated other projects that had to do with energy harvesting,
optics engineering, data management, environmental data, etc. These projects are listed below.

- Radiation Shielding Experiment (RSE)
- Electrical Power System (EPS)
- Data Management System (DMS)
- Rocket Energy Harvester (REH)
- MESA Harvester (MEH)
- Environmental Data Logger (EDL)
- Fiber Optic Gyroscope (FOG)
- Video Camera System (VCS)

We considered mission success to be defined as such, that all systems and modular payloads functioned according to their designs and data was collected. The integrated system was designed to begin collecting data at launch. Subsystems were to collect data based on design plan. Special altitudes of interest included 50 km to 150 km (Apogee), as we expected to change the most at these altitudes. The system as a whole was designed to run until power loss or data capacity were reached.
3.0 Payload Design

Modular Payload System

The design of the modular system uses a centralized shaft that acted as the ‘spinal column’ of the system, and holds the data and power lines. This design was chosen to provide strength and support to four trays. Each tray holds a series of individual components and experiments. The first tray holds both battery banks, the Data Management System, and the Environmental Data Logger. The second tray held three modular payloads including the Rocket Energy Harvester, MESA Harvester, and Video Capture System, as well as ballast. The top tray holds the Radiation Detection System.
Figure 2 - Full System Block Diagram
Electrical Power System

The electrical power system (EPS) was designed with two modified versions of the RockOn circuit in parallel to provide redundancy in case of errors. Upon activation of the G-Switch, the circuit will begin powering the modular systems from one of two pairs of Panasonic 18650 batteries in series. Those battery packs each provide upwards of 8.4 volts and 3400mAh at maximum charge. After G-switch activation, optocouplers ensure that power is delivered continuously throughout the flight while the batteries are not in danger of over-discharging. The threshold voltage of the optocouplers will prevent over-discharging. A reset switch was added to the design for use during testing only.

The EPS PCB was fabricated on an LPKF PCB machine and was designed to be single layer and entirely populated with through-hole components for ease of repair and reuse in future years.

To deliver as much power as possible, the power from the battery banks was not regulated in this design. Instead, the power will be regulated at each modular experiment according to its individual need. Since most modular experiments only required 5V, a universal power regulator was designed and distributed.

Figure 3 - EPS PCB Schematic and Layout

EPS Total Cost - $110.00
**Video Capture System**

The video capture system will start at T-0. The goal of this video captured is to capture images throughout the total flight path. The Adafruit Feather 32u4 adalogger will be the microcontroller that will start and store the video. This is a tested and trusted platform. The camera is the TTL Serial JPEG Camera with NTSC Video and it will communicate with the feather via I2C. The system only consists of these two components communicating with each other, only connected to the rest of the payload by the power supply.

![Figure 4 - Video Capture System](image)

**VCS Total Cost - $50**
Rocket Energy Harvester

The REH system is designed to harvest energy from gravitational and vibration forces expelled by the rocket. The Vibration Harvester is a mechanical subsystem of this modular payload and functions by absorbing ‘micro-impacts’ from a steel bearing with piezoelectric transducers and storing that energy in capacitors. The Gravity Harvester is another mechanical subsystem that harvest energy from piezoelectric transducers as a weight (steel bearing) compresses them. The transducers are positioned inside the harvesters such that they will achieve the optimal amount of generated energy from a Rocket launch scenario.

The mechanical harvesters were 3D printed with PLA filament (the black Gravity Harvester was printed with carbon fiber infused PLA). This material proved strong enough for this application through ample vibration testing.

The 4-layer PCB integrated two microcontrollers (ATmega2560 and ATmega16u2) and multiple sensors including a gyroscope and accelerometer. It stored its own data in a microSD card and also sent data to the DMS. The PCB was placed beneath the mechanical harvesters and acted as template for mounting to the modular tray system.

Figure 5 - Rocket Energy Harvester (models and fully assembled)

REH Total Cost - $375.14
Environmental Data Logger

The main goal of this modular bay was to collect environmental data during the flight for use with other payloads of our overall integrated system. This subsystem used a simple barometric pressure sensor for measuring altitude variations, as well as a temperature sensor, and was placed inside a modular bay next to the other modules of our system. The data that this subsystem collected was relayed to the data storage system during the flight. This subsystem consisted of an Arduino Nano, an Adafruit BMP280, and a SD card reader. It was powered using a universal 5V linear voltage regulator as shown in the image below.

![Environmental Data Logger](image_url)

*Figure 6 - Environmental Data Logger*

EDL Total Cost - $65.00
MESA Energy Harvester

The MESA Energy Harvester is designed to collect energy from vibration during the rocket launch using a piezoelectric cantilever beam. The beam is suspended above the perforated circuit board with a PLA 3D printed standoff. Energy generated by vibrating the piezo is stored in a storage capacitor after being regulated by a diode rectifier. An energy harvesting IC LTC3588 is used to control the harvested energy. The storage capacitor is regularly checked by an Arduino Nano and dumped when it reached 5V. Data is stored on a microSD card and also sent to the DMS. This system was designed to fit into a modular bay.

In addition to the energy harvester, this experiment uses a sensor bank called a Spaceboard to measure environmental, and positional data. This information is to be analyzed by the MESA high schools students as a learning tool.

![Figure 7 - MESA Energy Harvester](image)

MEH Total Cost - $179.13
**Fiber Optic Gyroscope**

The Fiber Optic Gyroscope (FOG) measures the rotation around the thrust axis of the rocket. The system consists of the FOG itself, a reference signal from a LY3200ALH MEMS gyroscope, and a microcontroller to read and store the data from both during the flight. The FOG is further broken down into the laser diode and driver, the optical system, and the detection photodiode.

The laser diode is a critical portion of the FOG system. It needs to maintain a constant wavelength and optical power output, or the FOG reading will drift off the true value over time. The Philips Optoelectronics CQF940 butterfly laser diode was chosen. It is an older 1310nm laser diode readily found on the used market, containing an integrated distributed feedback (DFB) grating and thermoelectric cooler (TEC). The DFB drastically narrows the gain window of the laser cavity, narrowing the laser linewidth to less than a nanometer. The center wavelength of the unit used was tested at 1312.8nm by Philips.

The TEC is driven by a dedicated MAX 1968 TEC driver IC. The driver requires a drive signal to moderate the current across the TEC. The drive signal is produced with the Maxim reference design found in HFAN-08.2.0, an operational amplifier based PID circuit that takes the thermistor in the diode package as input. The PID circuit was set to maintain 20°C.

An iC-Haus IC-WK MSOP8 driver was chosen to drive the laser due to its built in static protection and soft start capability. The driver is set to drive the laser diode at 3mW.

The optical system consists of a Sagnac interferometer made from a 30m coil of SMF-28 fiber optic cable around a 0.2m diameter holder and a singlemode 1310nm 2x2 fiber optic coupler. The fiber optic coupler and fiber optic patch cord were purchased as unbranded old stock.

![Figure 8 - Fiber Optic Gyroscope](image)

FOG Total Cost - $250
Radiation Shielding Experiment

The ultimate goal of this experiment was to quantify the effect of radiation upon complex electronic systems at varying distances from the surface of the Earth. Originally, we envisioned an FPGA-based radiation detection system. We tested this method without success. This was a result of radiation shielding on the FPGA themselves. Thus, we decided to build and use a radiation detection system using Geiger Muller tubes, and based on the RockOn schematic to focus our design on the radiation shielding rather than the detection. This system consisted in the following structural main components: RockOn HV board, Regulator, Arduino Nano, 4 Geiger-Muller tubes and 4 Tube in Shielding blocks connected to one Geiger tube each.

RSE Total Cost - $252.02
**Data Management System**

The main part of the DMS was the on-board electronics. This system was responsible for collecting data from 4 modules, separating the data and recording it to local storage in separate files. A Raspberry Pi Zero W was used for the MCU, while a USB hub was used to port all the connections. A 5v power regulator was used to maintain voltage from the power line while the Pi’s SD card stored the data. This system treated each module independently and had the ability to reconnect if needed. This system was designed to run for a total of 25 minutes, with the first 3 minutes having no connection with any module. System requirements for the Raspbian distribution of Linux that runs on the MCU are minimal. The secondary part of the DMS was the user interface. This small executable file searches its working directory and gives the user the ability to display .txt and .csv files. The DMS itself had relatively low prototyping costs (around $200), as the parts needed are quite common and no custom PCBs needed to be printed (aside from the power regulator).

![Figure 9 - Data Management System Block Diagram](image)

DMS Total Cost - $200
4.0 Student Involvement

The Oregon Tech team opted for a Shared Leadership Model such that tasks could be managed and completed by individuals who possessed those capabilities without seeking approval from a superior. This model was eventually chosen since it naturally fit with our team makeup and schedule. No one person needed to be present at all times which proved beneficial in completing tasks by deadlines. This method was further enhanced through our use of team communication and organization apps like Trello and Slack. The figure shown below corresponds to a graphical representation of the Shared Leadership Model implemented in our team.

![Shared Leadership Model Diagram](image)

**Figure 10 - Shared Leadership Model**

**Student:** Krystal Cruz  
**Major:** Electrical Engineering  
**Role:** Electrical Engineering Team Lead  
**Responsibilities:** Power systems and RSE design

**Student:** Wilson Davenport  
**Major:** Optical and Electrical Engineering  
**Role:** Systems Integration  
**Responsibilities:** Integration of systems and verification of user guide compliance.

**Student:** Diego Garrido-Mendoza  
**Major:** Electrical Engineering  
**Role:** Lead Electrical Engineer - RSE  
**Responsibilities:** Electrical design of RSE and EPS

**Student:** Zach Hofmann  
**Major:** Electrical Engineering  
**Role:** Lead Electrical Engineer - EDL  
**Responsibilities:** Design of EDL subsystem

**Student:** Andrew Horn  
**Major:** Software Engineering  
**Role:** Embedded Software Design and Integration  
**Responsibilities:** Co-Developer - DMS  
Lead Software Developer - RSE
Student: Caleb Ives  
Major: Electrical Engineering  
Role: Lead Developer - Modular Payloads  
Responsibilities: Community outreach, Systems Integration, and design of REH subsystem

Student: Chris Love  
Major: Electrical Engineering  
Role: Lead - MESA program  
Responsibilities: Develop MEH project, and facilitate HS student involvement.

Student: Jean-Luce Nabors  
Major: Mechanical Engineering  
Role: Project Manager/Lead Engineer  

Student: Thomas Pearce  
Major: Optical and Electrical Engineering  
Role: Lead Optical Engineer  
Responsibilities: Systems integration and design of EPS, RSE, and FOG.

Student: Steven Reeves  
Major: Software Engineering  
Role: Software Engineer Team Lead  
Responsibilities: Develop DMS project, and Systems Integration

Student: Jack Thomas  
Major: Mechanical Engineering  
Role: Mechanical Engineer Lead  
Responsibilities: Structural Design, simulation, testing, and fabrication
5.0 Testing Results

**Modular Payload System Testing**
Before the full mission simulation was performed, a series of smaller tests were conducted to ensure each aspect of the modular payload system was working correctly. The most essential components of this system are the structure itself, EPS, and DMS.

- **Electric Power System Testing**
  - Successful Tests:
    - All modular bays were connected and powered from two 18650 Li-Po batteries with fuses in place to isolate each modular bay.
    - Simulated T-3 functionality, only powering DMS. No other Modular bays were powered until G-switch was activated.
    - Simulated full flight time duration and all modular bays were still powered on.
    - Measured Power from power board and verified fully charged battery power of 3.7-4.2V. Even half-charged, the systems were still powered on with the back-up batteries connected if initial set of batteries were to fail.
    - Tested power system with all systems collecting data. A fuse was blown for the RSE. Adjusted with a large fuse.

- **Data Management System Testing**
  - Successful Tests:
    - Received data from 5 modules for full simulated flight time (30 minutes)
    - Ability to reconnect to module if connection lost during data collection
    - Capable of writing .txt and .csv files
    - T - 3:00 switch functional

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Fig. 11: (Left to right) Test data collected from MESA Energy Harvester, RSE, EDL, REH.
Payload Structure Testing

-Successful Tests:
  - The center of gravity was tested and ballast adjusted by hanging the payload from a segment of parachute cord. Tested 3 axis to confirm balance. Ballast was added to 2nd tray and to center column.
  - Preliminary spin testing was completed using a planetary gear motor coupled with a tachometer. A constant spin of 5Hz was conducted for 1 minute, and peak spin rates of 9.8Hz were achieved clockwise and counterclockwise. FOG and EPS were present for this test and had positive results.
  - Shake test was performed with the payload fully integrated (except for DMS), and fully powered. Tested with sine over random for vehicle level one in the thrust axis. All systems survived test except for one MOSFET that was not correctly staked down, which was been replaced and staked down.

Pre-FMS Subsystem Testing Results:
  - VCS -
    ■ Confirmed to be working correctly while connected to EPS.
    ■ Correctly stored data to local SD card.
    ■ A frame rate of 60 fps was achieved from 5MP camera.
  - REH -
    ■ Confirmed to be working while connected to EPS and DMS.
    ■ Correctly transmitted delimited data to DMS.
    ■ Successfully harvested energy from vibration testing in lab, but was unsuccessful during the system level shake test. (An electrical component disconnected and caused a short to occur. The problem was fixed and preventative measures were taken to avoid same problem during flight.)
  - EDL -
    ■ Confirmed to be working while connected to EPS and DMS.
    ■ Collected accurate environmental data according to lab equipment.
  - MEH -
    ■ Confirmed to be working while connected to EPS and DMS.
    ■ Successfully harvested energy during laboratory vibration testing.
    ■ Successfully harvested energy during system level shake test.
  - FOG -
    ■ Confirmed to be working while connected to EPS.
    ■ Fiber optic gyroscope characterized and working correctly.
    ■ Accurately spun up to -9.8 and 9.8Hz in solo spin test.
    ■ Successfully integrated during system level shake test.
    ■ Successfully powered for long periods of time (50+ min).
- **RSE -**
  - Confirmed to be working while connected to EPS and DMS.
  - Created three different shielding materials for Geiger Tubes with one unshielded.
  - Confirmed all Geiger Tubes were reporting radiation hits with varying frequencies using an oscilloscope.
  - Individual circuits for each geiger tube powered through 5V regulator and outputting data to DMS and the SD card.

**Full Mission Simulation**
The full mission simulation consisted of two steps:
- Construct the payload from a disassembled state
- Activate the payload using the G-switch and allow to run for 45 minutes.

The team was able to construct the payload in under 30 minutes without any errors. We wanted to test this procedure in case any unforeseen repairs needed to be made while at WFF. Then the payload was activated and it successfully ran for 45 minutes without any problems. The EPS and DMS were the main beneficiaries of these tests.

**WFF Shake and Spin Test**
At WFF, Wallops integrated our canister with the other school’s and performed a spin balance test, and the random vibration tests described above for vehicle level one in all three axis. The thrust test was significantly less violent than the test we did previously, due to the omission of the sine sweep.

All components in the canister physically survived, but the Video Capture System’s camera lens went out of focus slightly and the Fiber Optic Gyroscope did not record a signal on the fiber channel. A battery also came out of the holder enough to disconnect one battery pack, but the backup pack kept system power on for 5 hours before the payload was turned off.

The camera was refocused and staked down, and the Fiber Optic Gyroscope was removed from the canister, and worked fine. A lesson learned was the need to be able to test FOG functionality while integrated in the canister. The batteries were recharged and staked down for final flight assembly.
6.0  Mission Results

**Modular System (Structure & EPS)**
The modular system performed extraordinarily well during the flight. Success was defined by the system effectively supporting the modular payloads and subsystems for the duration of the flight. This was achieved with minimal errors.

**EPS -**
- EPS performed well during preliminary testing at WFF.
- Successfully recharged batteries for use during flight.
- During flight, EPS powered the modular systems for more than 2 hours.
- Upon inspection of payload and Modular Data, it was apparent that one of the battery banks became disconnected during flight. The secondary battery bank continued powering the system until the rocket was retrieved.

**Structure -**
- The structure remained fully intact.
- Nothing came loose or became dislodged during flight.
- Structure performed as expected.

**Radiation Shielding**
The Radiation Shielding Experiment successfully recorded valid data from all four Geiger-Muller systems during its flight. This data was written to the Arduino’s MicroSD card as well as sent over the serial data line to the Data Management System. Unfortunately, the results were inconclusive, as all four tubes recorded similar activity.

The table below documents the total number of radioactive hits recorded by each Geiger-Muller tube and its shielding material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Unshielded</th>
<th>Wax</th>
<th>Fe3O4</th>
<th>SrCo3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Hits</strong></td>
<td>686</td>
<td>631</td>
<td>633</td>
<td>668</td>
</tr>
</tbody>
</table>

There was a maximum variability of 8% different between the most active and least active counters.
- Least Active: Wax (631)
- Most Active: Unshielded (686)
- Difference: 35 hits
Data Management System

The Data Management System was successful in its mission to backup the experimental data provided by other modules. It was also successful in booting up at the T - 3:00 mark and waiting for the other modules to power on before recording. The DMS had mixed results in the actual recording of data from the other modules.

The Data Management System was connected to 4 modules total, the results were:

- RSE - Connection established, file created, no data recorded.
- EDL - Connection established and data written to the DMS successfully; data not recorded locally.
- MEH - Connection established; data recorded locally and on DMS.
- REH - Connection failed; data recorded locally only.

Rocket Energy Harvester

The REH, comprised of a gravity harvester and vibration harvester, partially worked. The vibration harvester collected energy for the duration of the flight and the subsequent retrieval process. However, the gravity harvester failed at a some point during the initial launch and then harvested nothing for the remainder of the flight.

The vibration harvester collects charge in a series of storage capacitors, then dumps that charge when it reaches 3.5 volts. Those trends can be seen in the following figures.

Figure 12: Vibration Harvester Voltage Data
Figure 13: Vibration Harvester Count Data

Vibration Harvester:
- Energy generated - 80 μJ per piezo element “micro impact”
- Power - 320 μW per piezo element
- Total Power at full activation during flight - 1.6 mW

Gravity Harvester:
- Inconclusive

Environmental Data Logger
The Environmental Data Logger was unsuccessful when recording its data to an SD card. However, because of the redundancy in our modular payload system the results from the flight were successfully captured by the Data Management System. The two graphs below display the pressure within the cabin and the change in temperature over the course of the 17 minute flight.
Figure 13 - Plots of temperature and pressure readings during the flight

Experimental results on the graphs shown above may indicate that the EDL reset while in flight; This could have led to the SD card failure detected later.

**Fiber Optic Gyroscope**

During both the shake test at WFF and the flight itself, the FOG did not record data on the fiber channel. The fiber likely got pinched during assembly. After the flight, the system was removed from the payload and was tested as working correctly.

**MESA Energy Harvester**

The MESA energy harvester functioned correctly for the duration of the flight, however, it was ineffective in harvesting energy. The plot shows that during different stages of the flight more energy was generated. For instance, during the launch there was a sharp peak in energy generation but it subsided while the rocket was in space (the capacitor discharge curve can be seen). Once the parachute was deployed and splashdown occurred, the energy harvesting resumed but not enough to fully charge the capacitor.

Figure 14: MESA Harvester Voltage Plot
**Video Capture System**

During launch, the Video Capture System created hundreds of empty .mp4 files. Upon inspection, it appears one of the data connection wires had wiggled loose, causing an intermittent connection.

7.0 Conclusions

**Modular System**

**EPS** -

The electrical power system worked as intended. Small improvements can always be made, including battery holders that make better connection to the batteries, but the EPS proved reliable, withstanding multiple failures during testing without power loss.

**Structure** -

The physical layout and structure of the payload was successful. Small changes could be made in the future to move wiring to a second wire channel on the opposite side of the WFF wireway, allowing a better tessellation of payload bays and more streamlined assembly and testing.

**Radiation Shielding Experiment**

The low variability of data between all four detectors leads us to believe the shielding was wholly ineffective.

We believe the small volume of shielding material was inadequate for the intensity of the radiation the RSE was exposed to.

**Environmental Data Logger**

It is possible that the EDL registered the variation of both temperature and pressure within the modular system. The EDL recorded data between approximately 26 degrees and about 37 degrees Celsius, and between 152700 [pa] and about 155500 [pa]. When it reached these maxima of both variables (temperature and pressure), the environmental data logger reset. This may have led to SD card failure. Count with limited to analyze and explain these phenomena; however, we consider this an opportunity to further study this system and improve it for future applications.
Data Management System

We believe the RSE failed to communicate with the DMS due to the way the Arduino Micro was designed. One of the interrupt pins on the Arduino was also the serial RX pin; Since we needed all four interrupt pins for the Geiger-Muller detectors, the Arduino was unable to establish a typical serial connection to the DMS upon start up. This inability to connect triggered an error-handling mechanism which then prevented the Arduino from attempting to write serial data over the USB line.

We are still unsure why the DMS was unable to connect to the Rocket Energy Harvester, but after some forensic analysis have decided that it was most likely caused by mechanical pressure on the serial bus port during the launch.

Rocket Energy Harvester

The data from the vibration harvester shows that a significant electric charge was generated by the vibration harvester during the flight. In the initial launch, energy was generated from the piezo elements oriented in the Z-axis.

While in space, very little energy was generated by the vibration harvester since there was very little vibration, but upon re-entry, vibrations resumed and so did energy harvesting.

Once the rocket landed in the ocean and during the retrieval phase, it harvested energy on the x-axis only, but in a linear fashion. This explains the two lines in the Count Data plot that extend far higher than the rest.

MESA Energy Harvester

The harvester did not effectively harvest energy. This is most likely due to a lack of an ambient vibration frequency onboard the rocket. This experiment was intended to provide a control for the REH system since the most common energy harvesters use piezoelectric cantilever beams.

The results when compared to the REH system show that a piezoelectric beam would most likely not be an effective energy harvester on a rocket since there is no ambient frequency. This system would be better suited for an automobile application where vibration has a high frequency and is very consistent.
Fiber Optic Gyroscope

The FOG did not collect data on the fiber channel during the flight, but it did collect data on the MEMS channel. The reference MEMS device is a superior measurement device even without failure, so the payload still provided the desired data to the other payloads, but it’s own experiment failed. The desired experiment was testing the fiber system under the high acceleration of flight, but it appears that the fiber was pinched during assembly, resulting in an excessive signal loss. This could be improved with more careful fiber coupling, going to a fiber optic cable with a thinner jacket, allowing more space for protective shielding around the coil.

8.0 Potential Follow-on Work.

A modular bay system was specifically designed to encourage future student experiments to be implemented easily. Allowing multiple experiments creates more data to collect and analyze.

The experiment results from this mission can be used to further explore radiation in space and how to improve radiation shielding.

The natural progression is to aim for the RockSat-X program. This introduces many more opportunities for research, as well as engineering challenges. As the 2018 RockSat-C team has learned to work together so well and develop such a technical payload, RockSat-X seems like the right direction. The development of such a modular system could definitely be improved upon and used for another RockSat-C mission as well.

For future OIT students, this years RockSat-C payload and lessons learned will be a resource to allow them to work on their individual experiments instead of worrying about completing a full system from scratch. The EPS and structure will be reused. We also hope to continue to involve local high school groups.
9.0 Benefits to the Scientific Community

Our goal was to create a universal mounting system for student capstone projects that would benefit from hostile environment testing. This modular system will help maximize the availability of functional experiments within the payload volume. The financial benefits of the this project will be recognized as more modules fly on the modular payload system. As ease of integration increases and time spent developing this process decreases engineering time will become less costly. Abstracting away the integration process from the end user saves them a lot of R&D time as well.

The intent of the Rocket Energy Harvester project was to find effective means of harvesting energy from a suborbital rocket using vibration and gravitational forces to eventually provide an abundant source of energy for powering circuitry while minimizing need for weighty battery banks. Even though the gravity harvester failed during the launch, the vibration harvester proved that this concept could be used to harvest energy effectively in this type of application.

10.0 Lessons Learned

Modular System

EPS

Testing was done prior to the payload check-in and after with all modular bays powered, but failed to access the secondary batteries due to faulty wiring. Failure to access the secondary batteries caused our primary batteries to insufficiently power all modular bays during the three days our payload was at Wallops leading up to launch. After final assembly, a power continuity check could be done to make sure all wires are connected properly.

Using Two Panasonic 18650s connected in series proved to be sufficient in providing more than enough voltage and amperage to each modular bay. The fuses implemented protection and isolation for individual modular bays. During the testing stages, it became difficult to tell if a fuse was blown or if the data was the issue. Having a separate indication of power versus data collection would improve this process.

Radiation Shielding Experiment

This experiment turned out to be a difficult challenge. Initially it was designed to incorporate multiple FPGAs and many other components. Unfortunately, a series of events prevented the team from fully pursuing this plan, and we eventually had to use our off-ramps.

In future projects like this, more organization and documentation will be required upfront so that everyone involved on the project will have a complete understanding.

DMS

Most of the modular bays had data successfully stored on the DMS after launch. The modular bays, such as the VCS, that failed, failed to get any data entirely. The EDL failed to collect data, but was saved by the DMS successfully.
Using a USB hub provided multiple data lines to be read by the Raspberry Pi Zero. This was made possible by eliminating the power connections in the USB to the modular bay serial data lines. Full simulation testing was not done, but a modified scenario of what could happen during launch. This prevented detection of specific issues related to launch. For further experiments, fully verified functionality should be done based on real-life scenarios.

**Modular Payloads**

REH - There are multiple changes that should be made to this system to make it function better. Piezoelectric transducers often come with weak electrical leads that need to be soldered better. This was the reason the Gravity Harvester failed, but it could easily be improved so this type of problem would not occur.

The storage capacitors chosen for this experiment were too small. The harvester generated more energy than expected and a significant amount of time was spent dumping energy while it could have been storing more and more. A supercapacitor with a significantly higher capacity should have been used.

**Team Organization**

With the purpose of improving the design and overall development process of our payload, we explored organizational factors that due to their nature may impact the quality and effectiveness of our work as a team, directly. To address those factors, we considered establishing clear role descriptions and how these roles are integrated in a single common effort. This solution also offers the opportunity to integrate this organizational structure to the Shared Leadership Model we implemented this year.

Also, considering the many variables and technical aspects involved in developing a modular integration system like ours, it is recommended to organize teams dedicated to complex tasks such as designing circuits and working on PCB layouts, etc., considering that many of these tasks are susceptible to human error. Tasks like these should be approached by teams and not assigned to one person only.

Another important consideration for future projects is to make sure that every team member is well informed about the specific projects being developed. This implies ensuring that each project lead educates the other team members with the goal of having a team ready to troubleshoot when needed, provide feedback and participate in the development process efficient and effectively. Additionally, using brief progress notes (two to three lines) to report every team member about modifications done by individuals or teams to the system, improvements, part replacements, etc., offers a greater chance for the team to be informed about the progress of the project as a whole and efficiently meet deadlines and goals.

**Budgeting**

In retrospect, the budget for this project was high enough that finding sponsorship should have been a more paramount objective. Fortunately, Oregon Institute of Technology was gracious enough to provide funding where we fell short. In future years, funding will be started earlier and given a higher level of importance.

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*Oregon Institute of Technology*

*RockSat-C 2018*

*Submittal Date:*

*July 27th, 2018*
Payload Design Figures:

Figure 15 - Universal power board schematic and model.

Figure 16 - Modular Payload Bay Model
Figure 17 - Bottom Tray design with EPS and two modular bays

Figure 18 - Tray Design Model
Figure 19 - Central shaft model (PVC)

Figure 20 - Tray support collar (aluminum)

Testing Results Figures:

Oregon Institute of Technology
RockSat-C 2018

Submittal Date: July 27th, 2018
Figure 16 - Example REH data capture

Fiber Optic Gyroscope

![Fiber Optic Gyroscope](image1)

Figure 15 - Fiber Optic Gyroscope Testing Results
Figure 16 - RSE Testing results when bombarded with radiation

Mission Results Figures:

Figure 17 - REH Gyroscope and Accelerometer Flight Data