FORT LEWIS COLLEGE

Fort Lewis College SpaceHawks

DemoSat 2021
Final Report

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Abstract

A payload was built and flown during the summer of 2021 for the Colorado Space Grant Consortium DemoSat balloon. The payload included two experiments, the first one was to see which color white or silver versus black was better at keeping a low internal temperature. The second experiment was to use a Peltier device to generate power by heating the device using solar insolation. To support the experiments there were two other systems the temperature control system (TCS) and the power management system (PMS). Finally, there was also a camera and a GPS to record the flight. Both experiments did not collect the appropriate data and did have noticeable errors in the data. The payload unfortunately did not perform as expected, with all systems failing to operate accordingly. However, all issues will be addressed and corrected in time for re-flight in November.

1.0 Mission Overview

Prior to launch, the goal was to construct a payload, that would conduct a set of experiments at high altitude and return usable data. Our payload launched on the Colorado Space Grant Consortium (COSGC) DemoSat platform which was operated by Edge of Space Sciences (EOSS), flight 301. The goal was to create a lightweight (1000 grams or less) payload that contained a set of experiments and electrical components.

2.0 Design

The design of the DemoSat included four subsystems: temperature control system (TCS), the power management system (PMS), camera and GPS, as well as two experiments: the color box and Peltier. The payload was designed to allow a three-quarter inch polyethylene tube to go through the cylindrical payload and accommodate both experiments.

2.1 Color Box Experiment

Error! Reference source not found. shows the block diagram for the Color Box experiment. Power was supplied to an Arduino Pro Mini which controlled a set of six temperature sensors. Then the Arduino wrote all data to a micro-SD card, saving all temperature data locally.

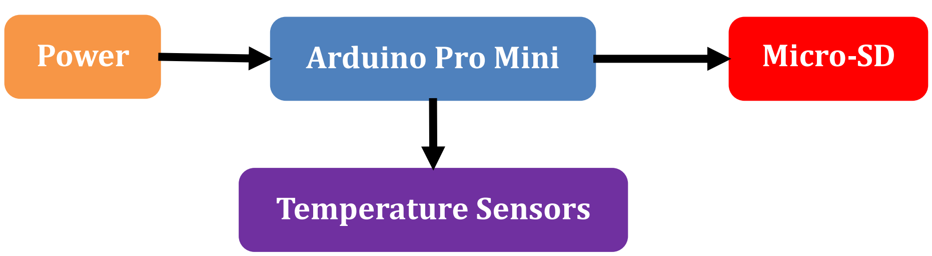

Figure 1: Color Box block diagram

Three-inch cubic boxes were constructed using black and white foam boards, shown in **Error! Reference source not found.**. The silver box was constructed using the white foam board and wrapped in aluminum foil and silver duct tape. The black box was painted a matte black using BLK 3.0 paint. The flight tube and temperature sensors were inserted through two sides of each of the boxes. In each of the boxes one of the sensors was secured in place, then the other sensor was threaded through to the next box.

Figure 2: The silver, black and white boxes as part of the color box experiment with the polyethylene tube threaded through.

2.2 Peltier Experiment

Error! Reference source not found. shows the block diagram for the Peltier experiment. Power is supplied to an Arduino Pro Mini which read the voltage from the Peltier devices. The data was recorded and saved locally to the SD card.

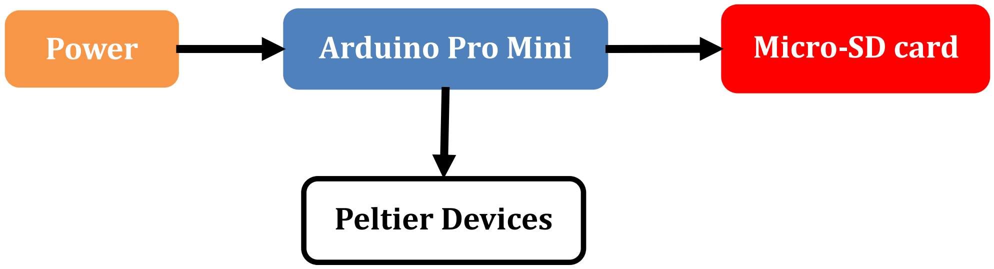

Figure 3: The Peltier block diagram.

Two Peltier devices were connected in series with the cold side painted matte black, using the same paint in the color box experiment. Two Peltier devices were held in a 3D printed housing, which can be seen in Figure 4. The output voltage was measured using the PMS system. Both power and voltage were recorded to the SD card.

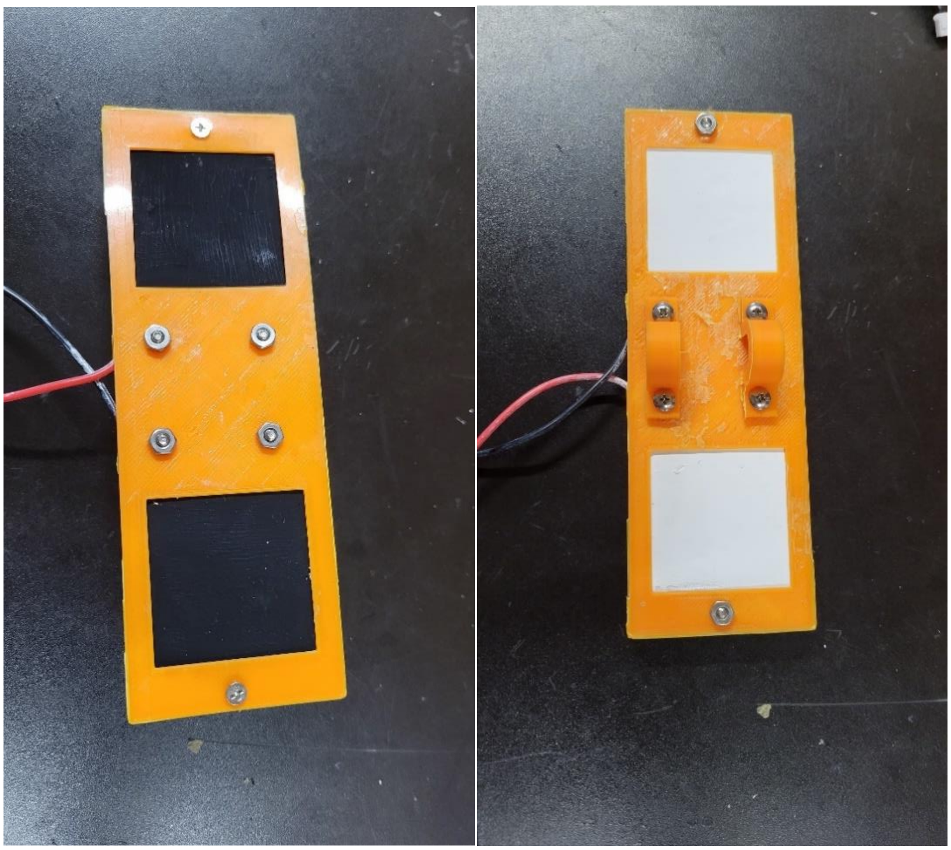

Figure 4: Peltier housing and experiment.

2.3 Camera

The camera block diagram is shown in Figure 5, once power was provided to the camera it would start to record. The camera also had an internal SD card, where all recorded footage was saved.

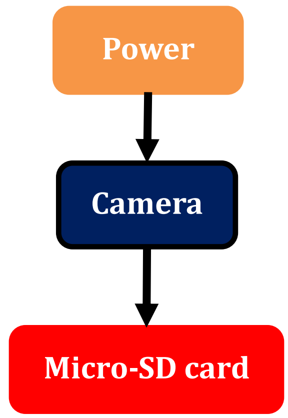

Figure 5: Camera block diagram.

During previous flights a mobius camera was used, however due to some unforeseen circumstances, a new camera had been purchased. Figure 6 below shows the new camera used during this flight. It is a *Nexar* dashcam, with an internal SD card holder. The design of the camera was bulky but light.

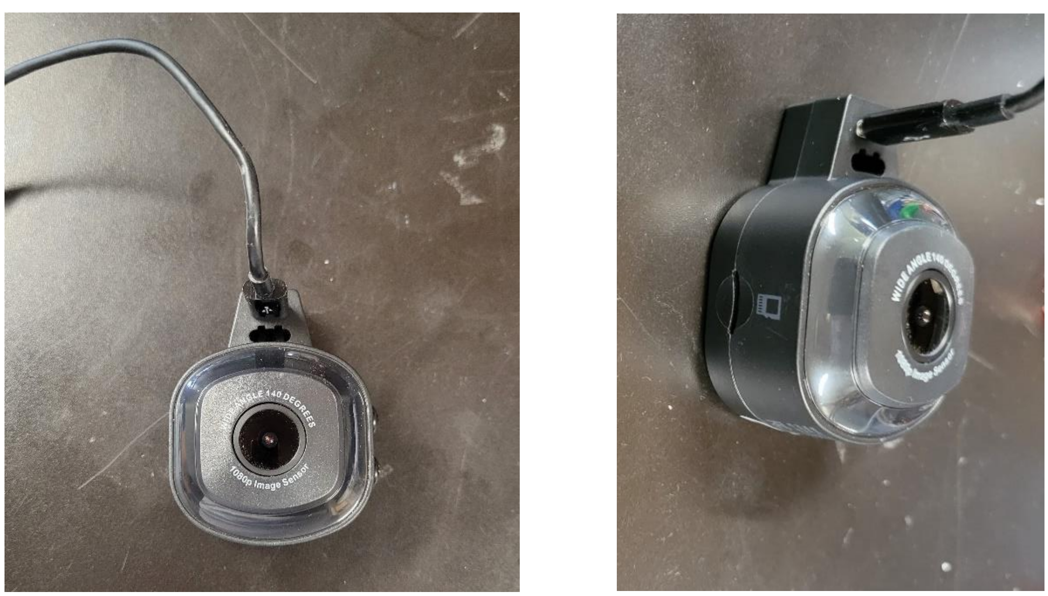

Figure 6: The camera used during the flight.

2.4 Power Management System (PMS)

For the power management system (PMS) the current sensors were placed in line between the battery bank supply lines and the individual system draw lines (PMS, TCS, camera, and GPS). Figure 7 shows the PMS block diagram where the Arduino Pro Mini writes data from the current sensors to a microSD card and control an LED display to provide quick external statuses for all systems. Two double pole double throw switches are connected to the battery and are accessible from the outside of the payload and recess within the PMS housing, so they are not thrown during the flight.

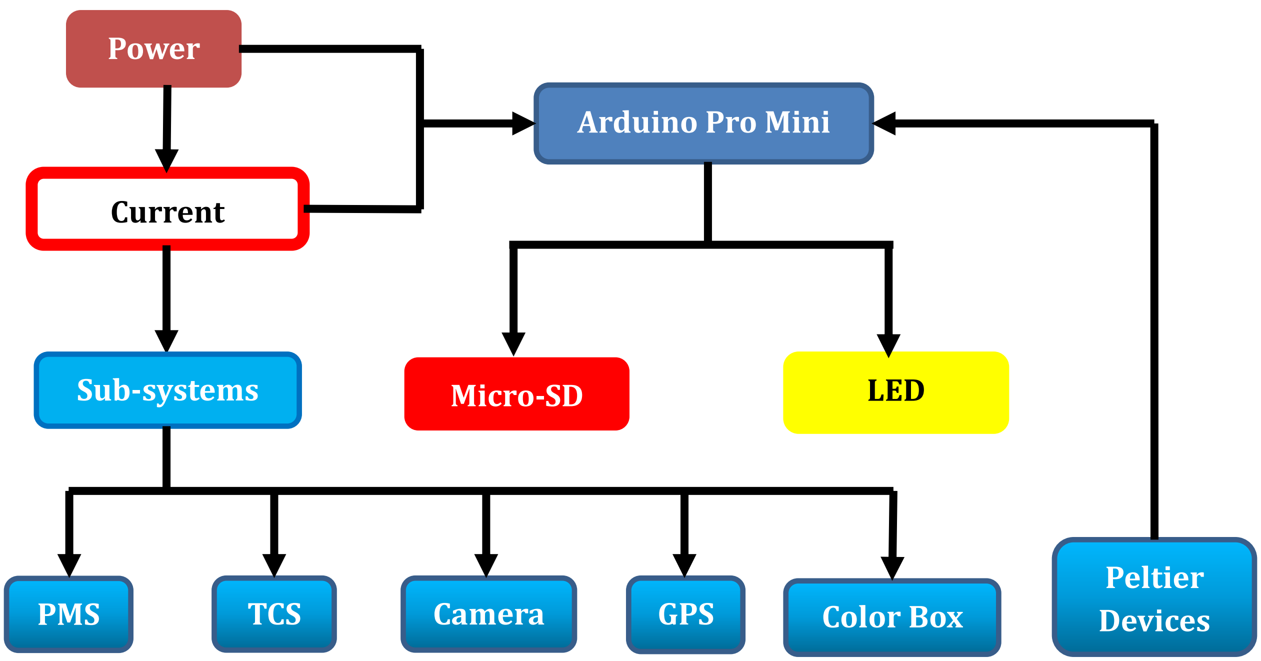

Figure 7: Power management system block diagram.

Figure 8 shows the circuit diagram of the power monitoring system (PMS). A 7.4V, 2200mAh battery was attached to the PMS system which sent power through LED indicators and then to Spark Fun INA169 dc current sensors for each of the four payloads. A 3.7V battery was attached to the channel leading to the GPS. The current data from each payload is recorded from the Arduino Pro Mini to a micro-SD every second. Each current sensor range was calibrated by adding resistors. The TMS current sensor, GPS current sensor, PMS, and Comms current sensor had 1Ω resistor with a current sense range of 35mA – 350mA. The Mobius Camera had a 0.1Ω resistor to give a current sense range of 175mA - 1.75A.

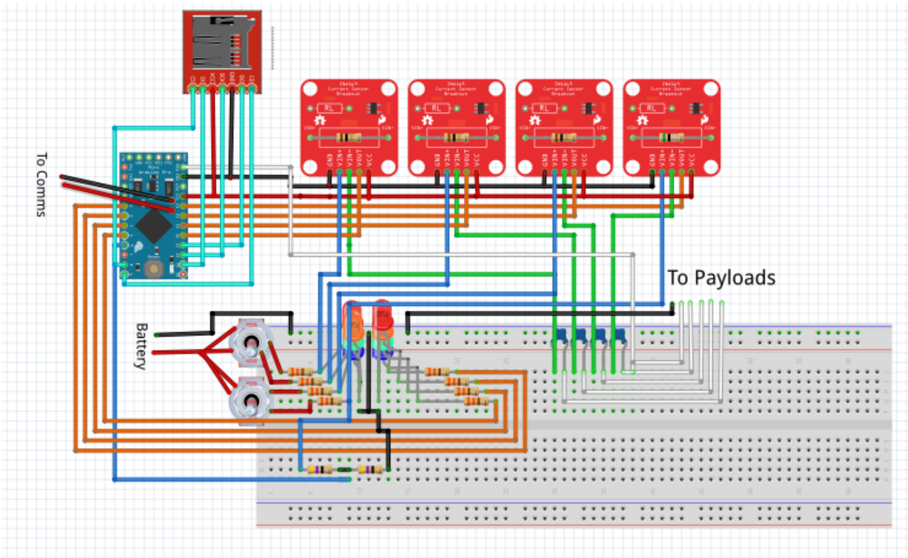

Figure 8: PMS circuit diagram.

To reduce the weight and size of the PMS system two custom printed circuit boards (PCBs) were designed. The first board is designed to hold the LEDs, switches, and provide an interface with the batteries, which can be seen in Figure 9, on the lower left side. The second PCB, shown in the center of Figure 9, was designed to efficiently wire the current sensors to the respective subsystems and wire the analog output back to the Arduino. The PCBs where design using the software, Fritzing.

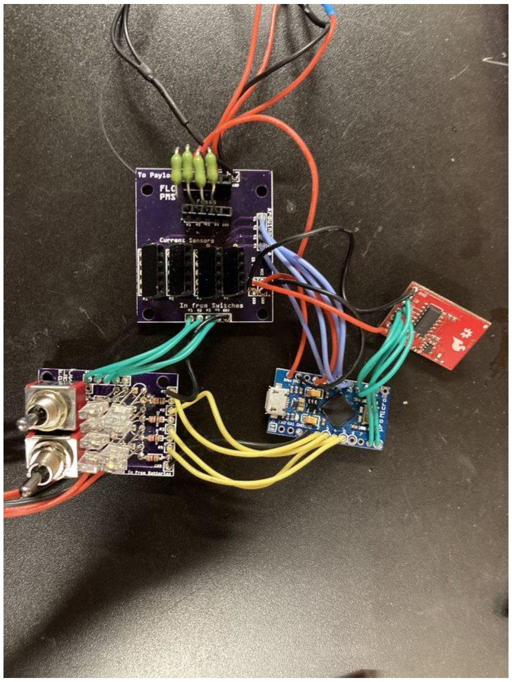

Figure 9: The PMS with the new PCBs.

This iteration of the PMS did not have a housing because the switches and LED were secured to the PCB, leaving the switches accessible and LEDs visible. The final assembly is shown on the left, in Figure 10 on the payload slider. The PMS PCB are centered over the payload sled with the DC current sensors, Arduino, fuses, micro-SD card reader, and batteries positioned over the flight string to fit best within the cylindrical capsule.

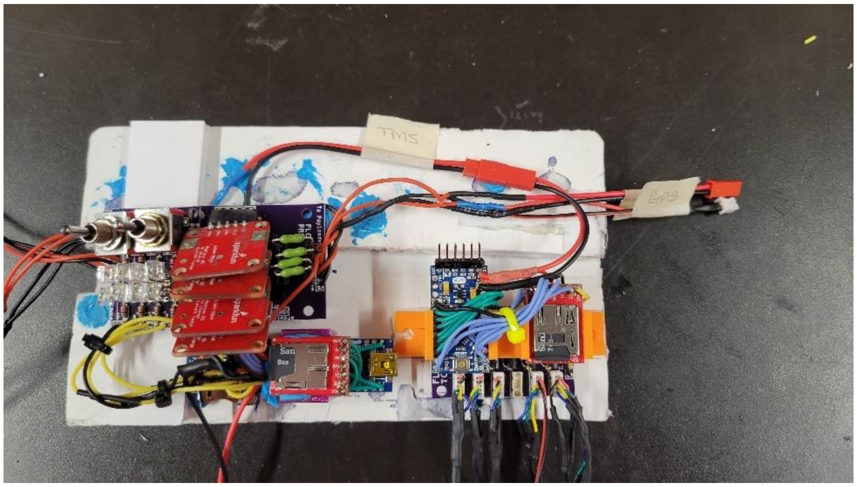

Figure 10: PMS on left side of the payload slider.

2.5 Temperature Control System

Figure 11 shows the block diagram for the temperature control system (TCS), it is powered by 7.4V battery. An Arduino Pro Mini will monitor the temperature sensors positioned near the battery and camera, which will turn on the resistor heaters as needed when temperature drops. All temperatures, heater statuses, and times are written to an internal SD card. Figure 12 shows the circuit schematic for one resistance heater and sensor.

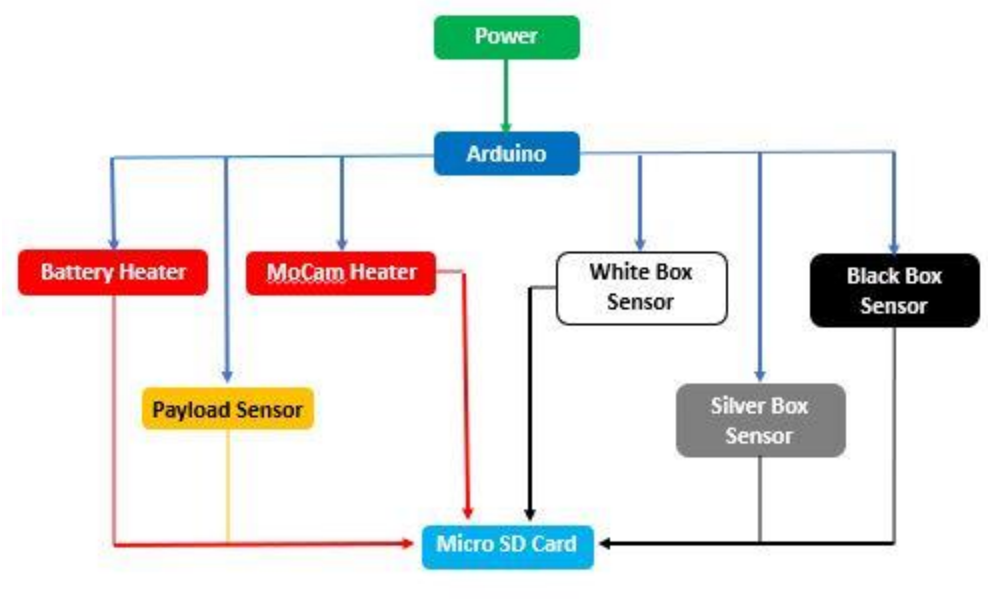

Figure 11: Thermal system block diagram.

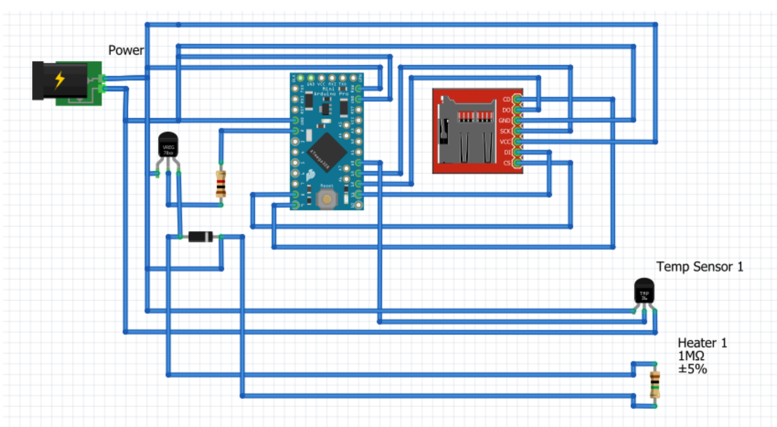

Figure 12: TCS circuit schematic, from previous designs, for one heater and sensor.

The TCS was redesigned this year to be smaller, like last year's design, the PCB significantly reduced the chances for faulty wiring. The new TCS PCB can be seen in Figure 13 Figure 13, which permitted the DemoSat to stay within the weight limit. Due to previously observed radio frequency (RF) interference during flights, shielded cables were used on this design to connect the temperature sensors to the Arduino.

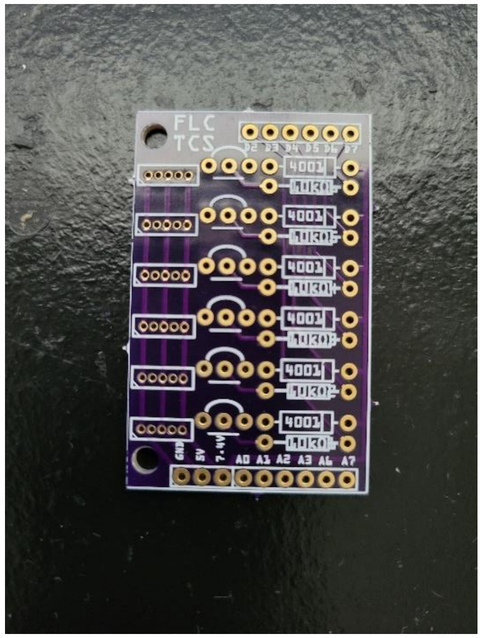

Figure 13: PCB design of the TCS.

2.6 GPS

Figure 14 shows the Altus Metrum Tele-GPS used on the payload. This flight computer, developed for use in tracking high-powered rockets, has an on-board transmitter for the 434.55 MHz band. Basic telemetry is transmitted: latitude, longitude, and altitude.

Figure 14: The Tele-GPS used during flight.

2.7 Structure

2.7.1 DemoSat

Figure 15 shows the outer structure for the DemoSat. The flight tube was embedded in the middle of the sled and through the colored boxes. The payload cylinder was 4 inches in diameter and 7 inches long. Each of the colored boxes are separated by approximately 2.5 inches and they are 3 inches square. Structures are connected to the polyethylene flight tube with a gripper system and hose clamps. The grippers are seen in Figure 16.

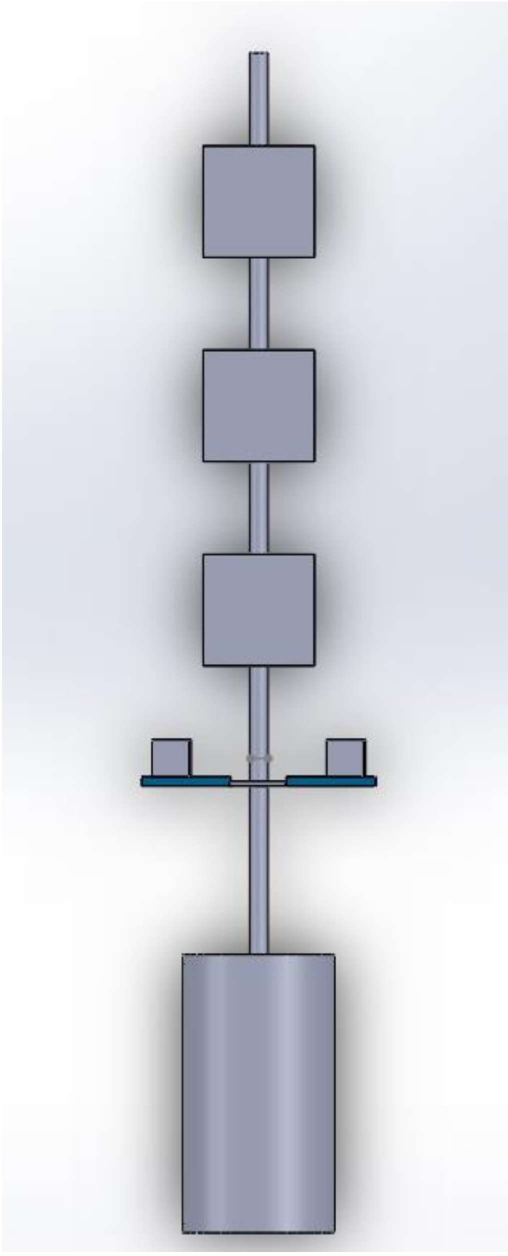

Figure 15: Outer structure for DemoSat.

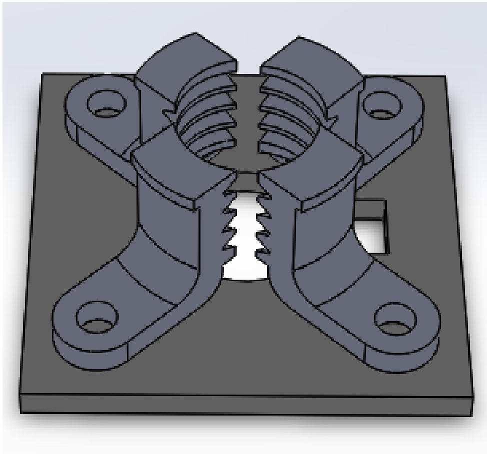

Figure 16: PLA gripper system for attaching structure to flight tube.

Figure 17 shows the completed DemoSat sled structure, with all internal systems mounted and readied for flight. The sled was made from foam core to minimize weight.

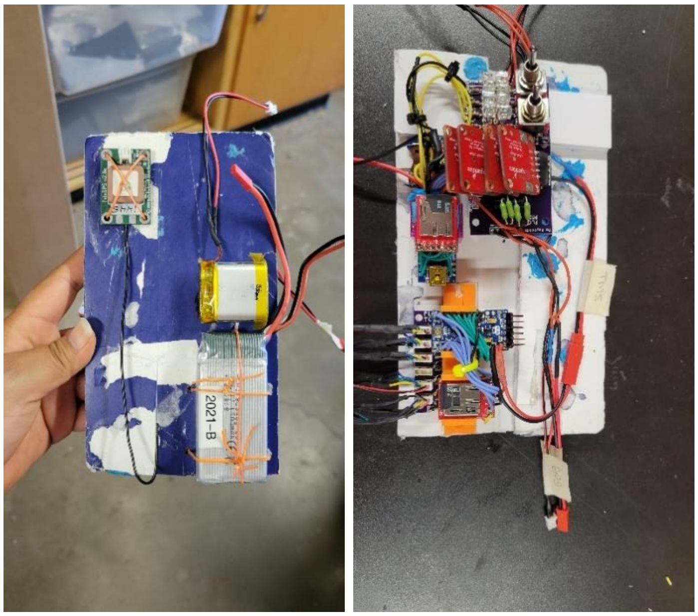

Figure 17: Inner sled structure.

3.0 Project Management

3.1 Student Team

Because this project was done in parallel with the HASP project each of the team member's roles were limited to that as shown in Table 1. However, each member was responsible for ensuring all subsystems work together, as well as that the whole payload was functional.

Table 1:Task assignments.

Task	Person(s) in charge
Space Grant Affiliate Director	Dr. Charles Hakes
Management and Documentation	Roxie Sandoval
Power System	Jesse Urban & Roxie Sandoval
Camera	Roxie Sandoval
Peltier Experiment	Roxie Sandoval
Thermal System and Color Box Experiment	Roxie Sandoval
Structures	ALL
Testing	ALL

3.2 Project Timeline

The DemoSat project was completed in parallel with the HASP project, with the goal of being completed by July 24th, the Friday before integration week.

3.3 Mass Budget

Table 2 shows the mass budget for each of the payload's components before they were installed on the flight tube. The flight tube and mounting hardware resulted in a payload that was heavy than our initial estimates. The final assembled weight of the payload was 868 grams.

Table 2:Weights of the sub-systems

Subsystem	**Weight (g)**
Camera	55.5
CBAP(Peltier)	70.1

CBAP(Box)	127.2
Internal Structure Pallet	47.6
Power Control	49
Battery	87
GPS	33.9
Payload sled	95.0
Flight tube	57.1
Flight tube grippers	39
Misc. (wires and glue)	23.2
Total	684.6

3.4 Monetary Budget

Table 3 shows the financial budget for the DemoSat payload. Large contributors to the final cost came from the GPS transmitter and new camera. All housing components were 3D printed using the printer at FLC, and small hardware pieces were purchased at a local ACE Hardware.

Table 3: Approximate expenditures for Fort Lewis College participation in DemoSat

Source	**Part**	**Units**	**Unit Price ($)**	**Total ($)**
Sparkfun	INA169 Current Sensor	4	9.95	39.80
Sparkfun	Arduino Pro Mini	4	9.95	39.80
Sparkfun	Ribbon Cable	1	4.95	4.95
Western digital	Micro SD Card (128Gb)	1	24.99	24.99
Wal-Mart	Nexar DashCam	1	79.95	79.95
Newegg	Micro SD card (4Gb)	4	6.35	25.40
Sparkfun	microSD Breakout	4	5.50	22

Sparkfun	TMP36	12	1.50	18
Altus Metrum	Tele GPS	1	200.77	200.77
Misc Supplies(solder,wire,ect)		1	20	20
ebay	Peltier device (5)	1	15.89	15.89
			TOTAL ($)	491.55

4.0 Testing Plan

4.1 Functional

A functional test was conducted by performing an endurance test to ensure all components would work remotely, as well as verifying the proper functionality of the programmed codes. This included multiple individual component tests and a cold test to ensure electrical stability. The cold test involved putting the payload next to dry ice for two hours. The payload passed this test because there was data on each of the SD cards.

4.2 Structural

In addition to the functional test three structural tests were also completed: a whip, drop, and stair pitch test. These were performed to ensure the payload will stay on the flight tube and string and will be able to withstand landing after launch. During the drop test, the payload landed on one of the endcaps which broke, which was modified to withstand greater impacts. The payload did pass all structural tests. To pass the structural tests the payload must not come off the of the flight string and the payload must not break upon impact.

5.0 Results and Conclusion

5.1.1 Peltier System

This year there was a few changes made to the Peltier system, such as the removal of the heat sinks and the housing was made smaller to allow more insolation to the surface of the devices. However, upon retrieval of the DemoSat the data did not look remotely close to what was anticipated. The time from the arduino was said to be about 77,600s! As shown in Figure 18, there was no power provided from the devices except the little outliers of 0.0049W, this could be due to a bug in the code or faulty wiring that may have gotten loose during shipment.

Troubleshooting will start with the code and from there each of the components from the Peltier and PMS will be tested again before re-flight.

5.1.2 Color Box Experiment

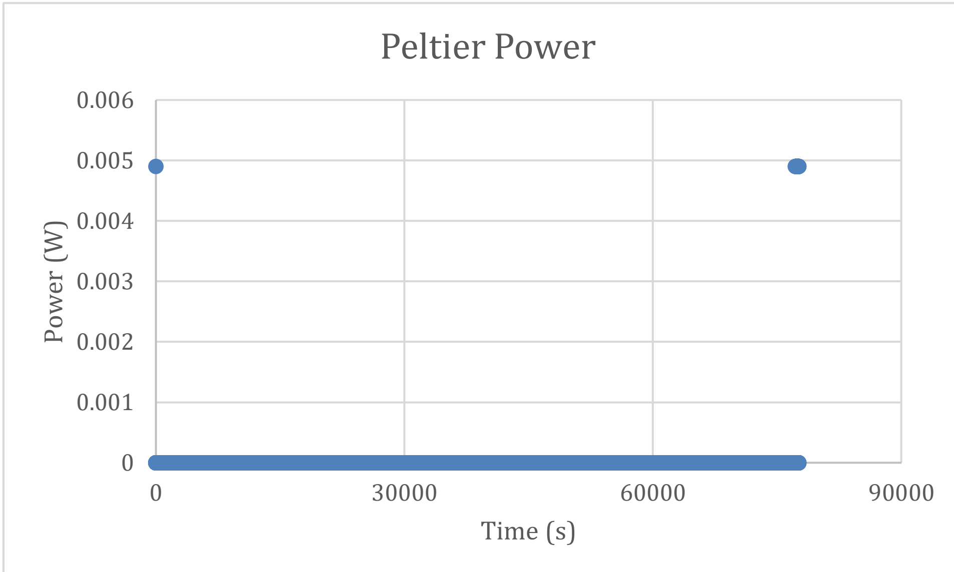

Figure 18: Peltier data collected during this flight.

After the DemoSat returned, the TMS was found to have a loose wire from the arduino to the SD card reader that affected data collection, because the time was off as well, and the sensors read to over 100°C, which is completely wrong and unexpected, as shown in Figure 19. Not only was there multiple data set collected but none were during flight, or the loose wire kept the TMS from collecting appropriate temperature data. Each of the sensors stayed within the same realm of 5 degrees from each other and behaved similarly. The loose wire for the TMS will be secured and tested again.

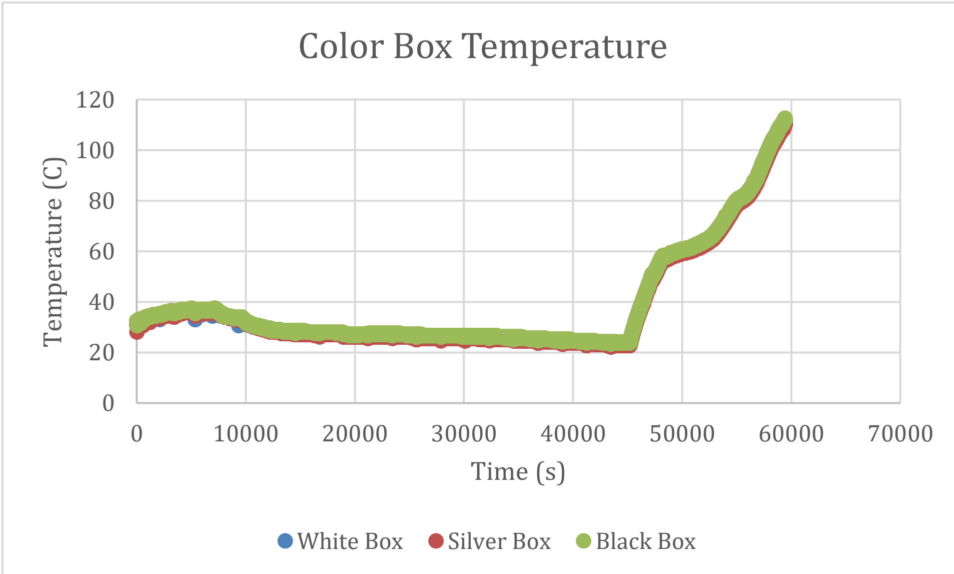

Figure 19: Color box's temperatures.

5.1.3 Camera System

A new camera system was used during this flight; however, it was unable to film any footage of the flight. It was tested and was confirmed to be filming and saving the video prior to shipment. For unknown reasons the new system failed to save any video from the flight. The new system did suggest an app for ease of use, and the app was used to confirm video was being recorded. This could possibly be a reason video did not record on its own and will be investigated in detail prior to relaunch.

5.1.4 Temperature Management System

As shown in Figure 20, the sensors, unfortunately behaved the same as the sensors in the color box experiment. They showed the same increase in temperature.

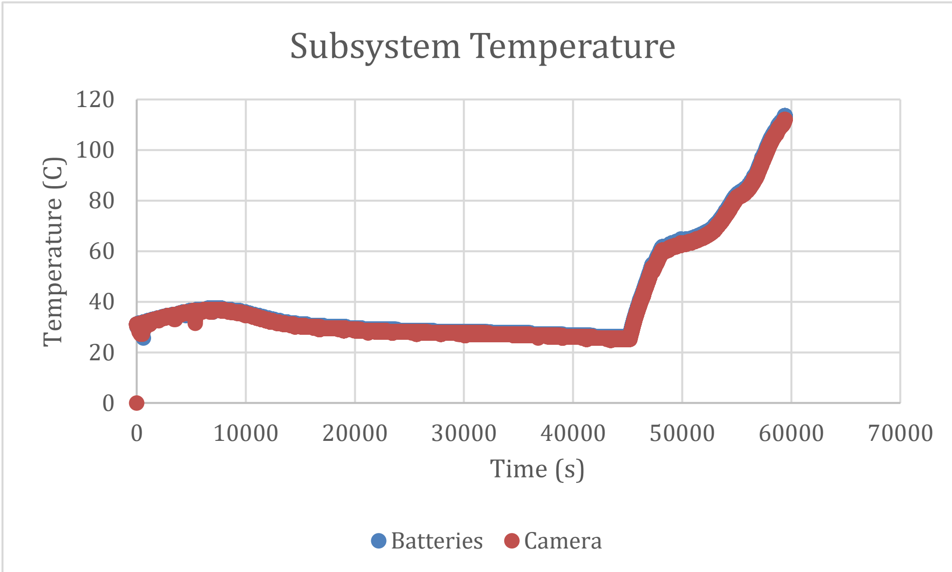

Figure 20: Temperature of both subsystems.

5.1.5 Power Management System

Figure 21 below shows the current draw from the PMS. Which shows a gradual decrease over time, this could explain if the system had remained on. The timing for the PMS was either off or the system continued to draw power for nearly 21 hours, this is still being investigated and will be corrected before relaunch.

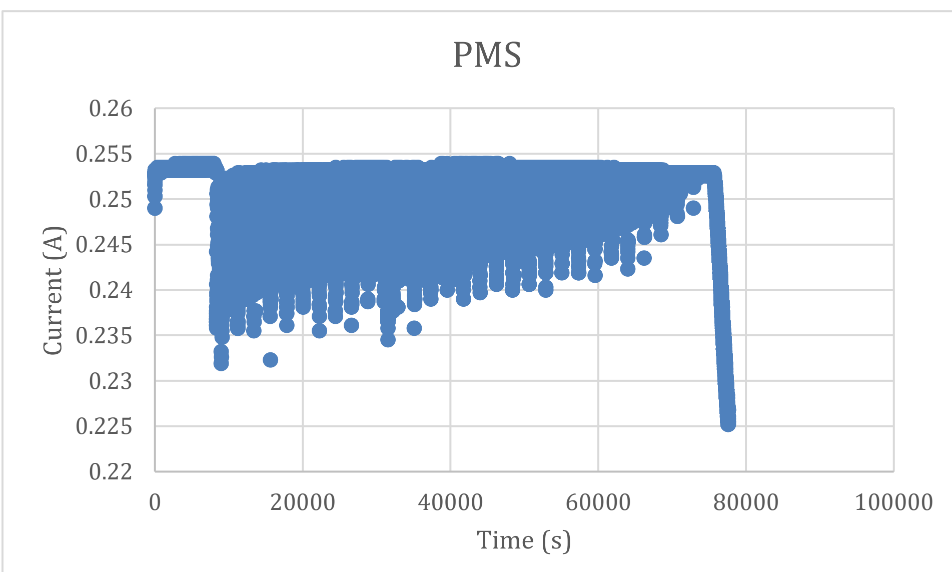

Figure 21: The current draw from the PMS.

5.1.6 GPS

Sadly, the GPS did work during this flight, but due to outdated firmware, the GPS did not save any data. All systems were confirmed running prior to shipment but there were some bugs in the systems that will all be addressed before re-flight.

5.2 Failure Summary

From the data analysis, most if not all systems failed during flight. The TMS did not collect the appropriate data this was most likely due to the loose wire found upon retrieval. The PMS somehow collected data for 21 hours for unknown reasons. The camera failed to save any usable footage; this too is being investigated.

6.0 Conclusions and Lessons Learned

The team learned to troubleshoot. This summer had given more unanticipated problems that troubleshooting seemed to be all the team did most of the time. For example, one day all systems will work properly and as expected, then the next the system would stop saving to the SD card or the arduino wouldn't work as coded. It's been a tough summer, but the team got through it and is planning to re-fly the DemoSat with the same experiments.

7.0 Message to Next Year

Continue improving upon the PCBs, which decreased the weight of the DemoSat, there is always room for improvement. Comments on the code helps and will aid in the understanding for those who are not arduino proficient. Designing, building, and troubleshooting takes longer than expected so time management is a must.