

Colorado Space Grant Consortium

DEMOSAT

Team Hot Air

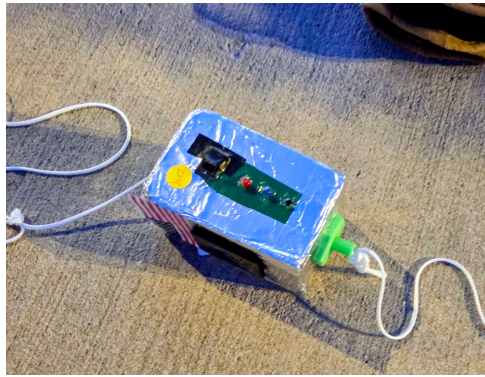


Figure 1: Team Hot Air's DemoSat

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Report Date: 4/16/2025

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1.0 Mission Overview

The mission is to investigate data gathered at high altitudes to allow for higher pilot and aircraft efficiency. It is expected that the payload will collect more accurate data compared to governmentally standardized ones. Additionally, solar panels were investigated to determine their effectiveness after high altitude travel, as well as the difference in charging efficiency when compared to ground controls. Each test performed was requested by one of three stakeholders, a fixed-wing pilot, helicopter pilot, and a hot air balloon pilot. The fixed wing pilot requested acceleration, properties of air, and aircraft performance as planes are typically more efficient when flying at higher altitudes due to less air resistance. The helicopter pilot requested tests on efficiency of solar panels. Lastly, the hot air balloon pilot requested the testing of density altitude and oxygen partial pressure as the FAA requires supplemental oxygen in hot air balloons that go above 12,500 ft. Team Hot Air’s mission statement is to collect experimental data at high altitudes to make pilots and aircraft more efficient.

2.0 Requirements Flow Down

The requirements for Team Hot Air’s DemoSat mission are derived directly from the mission statement, which focuses on collecting high-altitude atmospheric and performance data to improve aircraft efficiency and pilot/passenger safety. Top-level (Level 0) requirements define the overall mission objectives, while lower-level (Level 1) requirements break these objectives into measurable and testable engineering specifications. This flow-down ensures that each subsystem and experiment contributes directly to achieving the mission goals.

Requirements Flow Down Table

| Mission Objective | Level 0 Requirement | Level 1 Requirement |
|--|---|---|
| Collect high-altitude atmospheric data | The system shall measure atmospheric properties during flight | The payload shall measure temperature from -50°C to 50°C |
| | | The payload shall measure pressure from ground level to 100,000 ft equivalent |
| | | The team shall calculate density altitude using collected data |
| Improve aircraft performance understanding | The system shall measure parameters affecting aircraft efficiency | The payload shall record acceleration in 2 axes ($\pm 16g$ range) |
| | | The system shall log altitude vs. acceleration data throughout flight |
| Investigate solar panel performance | The system shall evaluate solar panel efficiency at altitude | The team shall measure voltage before and after flight |
| | | The team shall measure in-flight data to ground control data |

| | | |
|--|--|--|
| Support pilot safety (oxygen requirements) | The system shall analyze pressure, humidity, temperature, and acceleration which will be used to calculate oxygen availability | The team shall estimate oxygen partial pressure from pressure data |
| | | The team shall calculate altitude where oxygen drops below safe thresholds |
| Ensure reliable data collection | The system shall store and transmit experimental data | The payload shall log data every half second |
| | | The system shall store all data onboard for post-flight retrieval |
| Operate in high-altitude environment | The system shall function under near-space conditions | The payload shall operate in temperatures down to -50°C |
| | | The payload shall remain operational up to 100,000 ft altitude |

3.0 Design

The mission is to be completed by April fourth, in which the payload will be launched. The payload has a max weight of 600g, which only 210g was utilized. The size of the final payload was 12.7 cm x 8.89 cm x 8.89 cm. As per hardware requirements and limitations, the payload was to be within the scope of the base payload kit, no additional parts outside of the solar panels were used. For the mission, all of the hardware was provided by the Pikes Peak State College Engineering department in the form of spark fun high altitude balloon payload kits, which components are listed in [Section 5](#). The structural system will protect components of all other systems and attach to the thermal control system of non-conductive insulation. These make up the environmental protection system sheltering the other systems from low pressure, wind, and moisture. The power system supplies the power needed by the command and data handling system (C&DH) like the Arduino. The C&DH includes code that controls sensors in the sensor/payload system and logs data. The design complies with the requirements of the DemoSat program, it is within the weight requirements, size requirements, and it was built to complete the mission, collecting acceleration data, velocity, humidity, pressure, and charge solar panels. While originally the hot air balloon pilot stakeholder requested a time released weight be dropped off the payload to see the change in acceleration afterwards, components of the payload dropping off is outside DemoSat regulations, so this part of the design was not completed.

The mission will be completed by using pressure, humidity, acceleration, and temperature sensors to calculate the density altitude using the following equation:

$$\rho = \frac{p_d}{R_d T} + \frac{p_v}{R_v T}$$

Where:

- ρ = air density (kg/m^3)
- p_d = dry air pressure
- p_v = water vapor pressure
- $R_d = 287 \text{ J}/(\text{kg} \cdot \text{K})$
- $R_v = 461 \text{ J}/(\text{kg} \cdot \text{K})$
- T = temperature (Kelvin)

Aircraft performance will be measured directly from the sensors. Oxygen partial pressure will be calculated using Dalton's Law of Partial Pressures. The solar charger rate will be determined manually using a multimeter before and after flight for solar panels on the payload and ground controls.

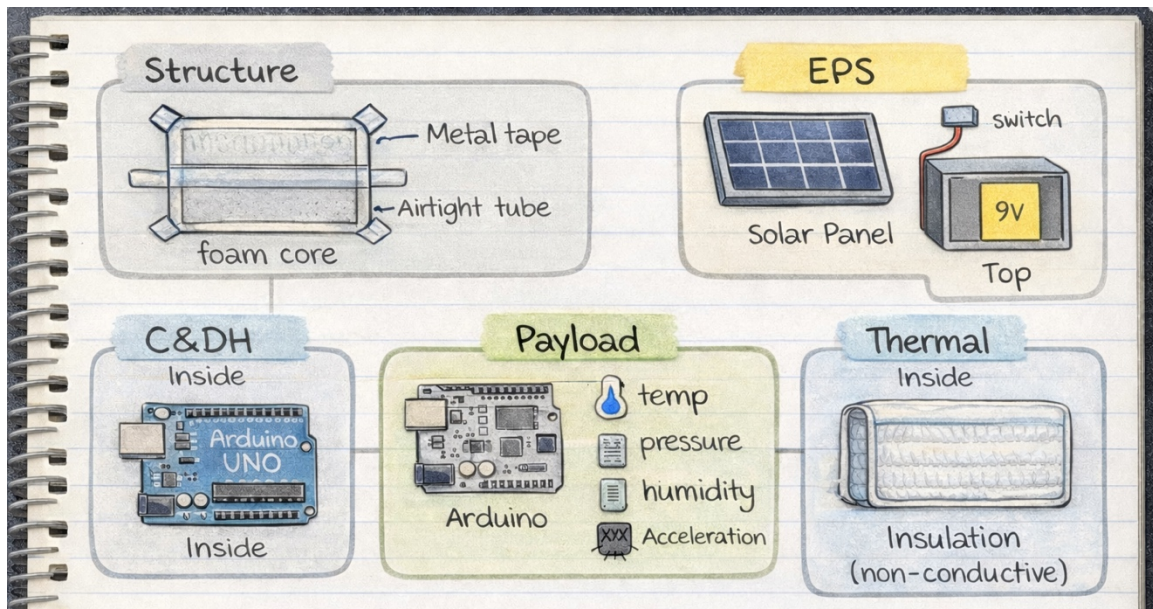


Figure 2: Functional Block Diagram

Parts List:

- Foam core
- Insulation
- Flight tube
- Foil tape

- 4 Solar Panels
- 9V battery
- Arduino Uno
- Temperature, pressure, humidity, acceleration sensor

4.0 Management

Alease was the original member of this team. She started the project and had meetings with stakeholders. Her main role in this project was ensuring the team had the parts necessary to test the stakeholder’s requests and creating and presenting progress reports presented to Annie Strange. Samuel did most of the manual work of building the box and connecting all the parts together. He was also instrumental in ensuring the Arduino code was working properly. Nick joined the team late in the process but was able to help with the final report and will be presenting at symposiums.

Subsystems:

Structure – Samuel

EPS – Alease and Samuel

C&DH – Samuel

Payload – Samuel

Thermal – Samuel

| Project Schedule | |
|--------------------|--|
| March 1 - 7 | Gather Materials Begin Assembly Stakeholder Meetings |
| March 8 - 14 | Assembly Coding Solar Panel Testing CDR |
| March 15 - 21 | Print and Test New Flight Tubes Sensor Testing Structural Testing |
| March 22 - 28 | Abstracts for CSURF and Research Symposium submitted |
| March 29 – April 4 | Freeze Test Structural Test Flight Battery Test Repair FRR Final Weight Flight |

5.0 Budget

Payload Kit - \$150

- Accelerometer
- Pressure Sensor
- Temperature Sensor x2
 - o 1 interior
 - o 1 Exterior
- Arduino UNO MicroController
- LED Lights x6
 - o 4 interior lights
 - o 2 exterior lights
- Micro SD card
- 330-ohm resistors x6
- 9V batteries x2
 - o 1 Test Battery
 - o 1 Flight Battery
- Power Switch
- Humidity Sensor
- Battery Connector
- Power Supply for Arduino
- Payload Code for Arduino
- Styrofoam Shell
- Foam Insulation
- Solar Panels x4
 - o 2 Flight Panels
 - o 2 Control Panels
- Magnet

All parts from the kit were provided by Pikes Peak State College and didn't need individual weight as it was already below the requirement. The final weight of the payload was 210 grams, while the limit was 600 grams.

6.0 Test Plan and Results

To ensure the payload worked correctly there were three tests: the drop test, spin test, and the freeze test. The freeze tests main purpose is to ensure viability of components within the scopes of the stress test. The freeze test results ended with the battery shutting off mid test, but showcased viability of the payload.

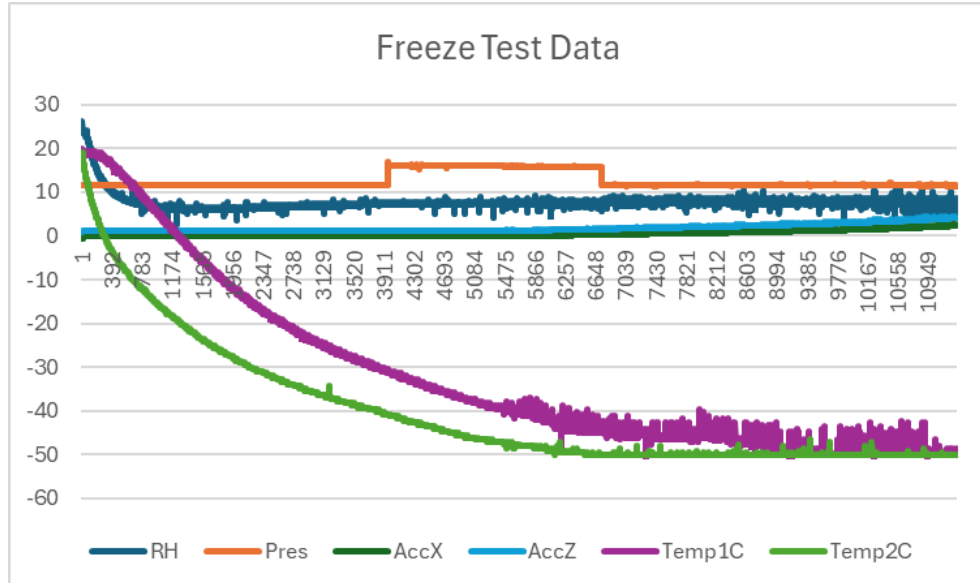


Figure 3: Freeze Data Test Results

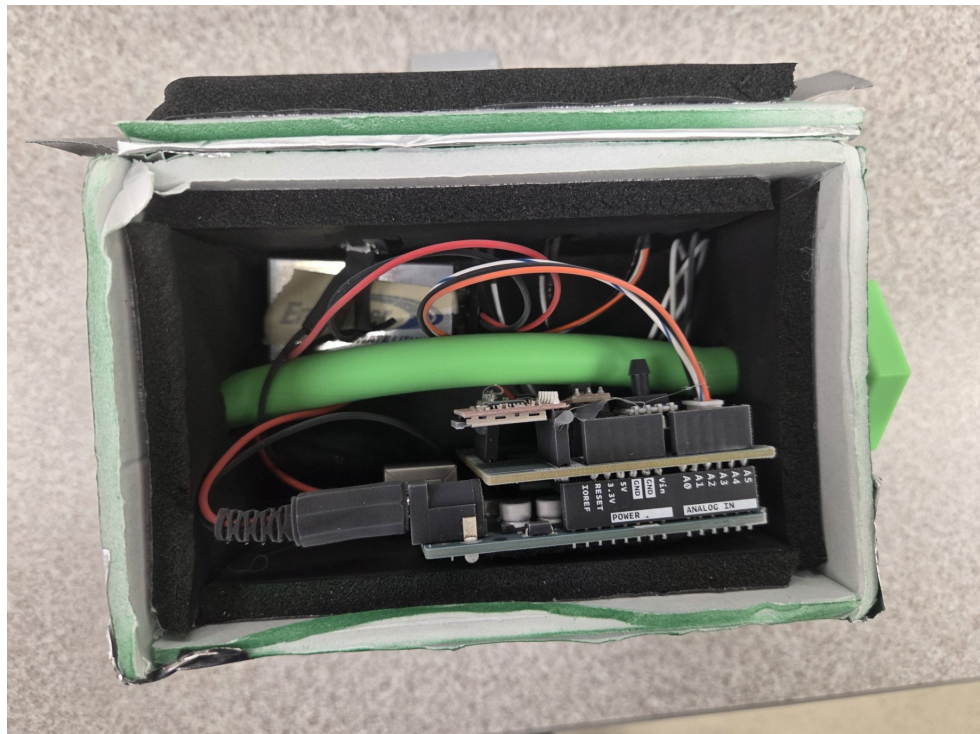


Figure 4: Structure after Freeze

As shown in figure [5], there was a cut off due to insufficient charge. The 9 V battery used was a test battery so that the flight battery stays charged. It was a non-rechargeable battery and would have been proven defective during the actual flight. Other than the test battery failing, the parts still show no damage as well as the shell. The Solar panels showed no problems after the test which gave a clear result that nothing happened. After fully inspecting that all the other tests worked, it was time for the other tests.

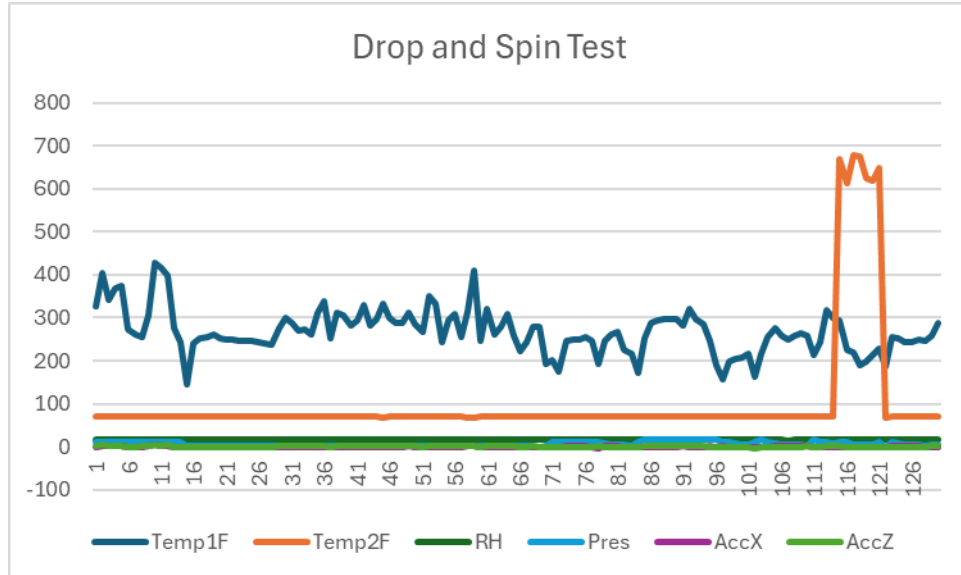


Figure 5: Spin and Drop Test Data



Figure 6: Structure after Spin and Drop Test

The spin and drop test indicated a critical failure with the temperature sensor caused by faulty wiring. Comparing the data from Figure [3] and figure [5], the tests didn't show anything abnormal without a reason. The solar panels experienced no failures during any of the tests, indicating flight success.

7.0 Expected Results

All the sensors were tested individually and all together before flight to ensure data was being recorded properly. The data was inserted into an excel document where formulas needed were used to create visual representations of results.

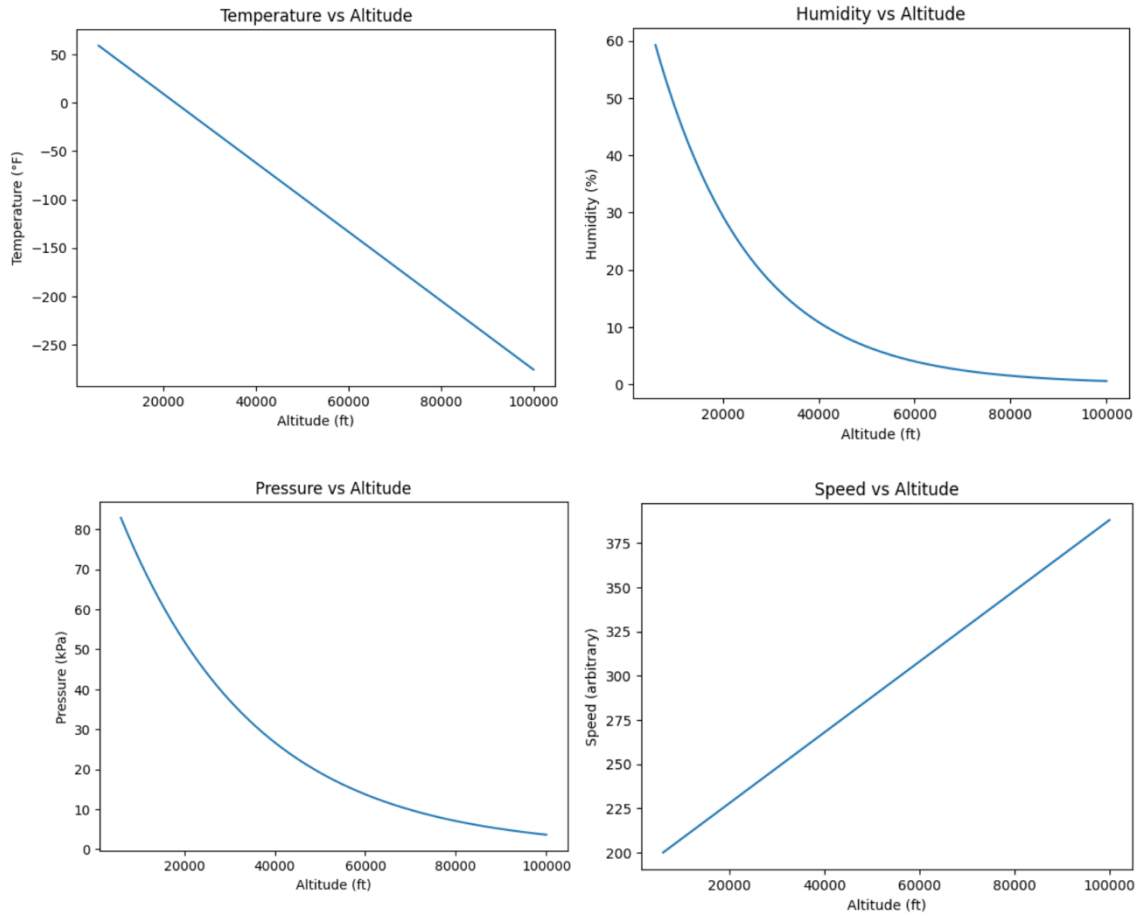


Figure 7: Predicted Results

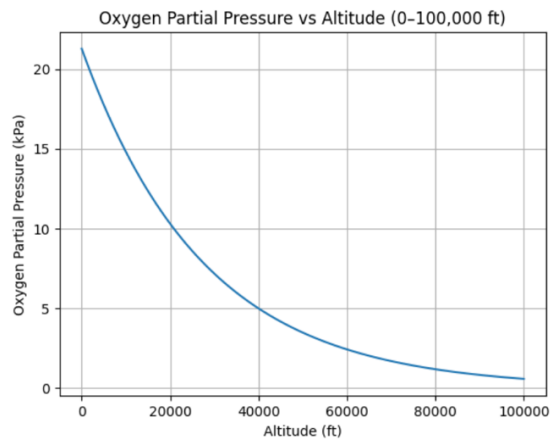


Figure 8: Predicted Results

It is predicted that the solar panels on the ground will charge much slower than the ones in flight as they will be much closer to the sun. The density altitude measurement should be roughly a 1:1 line with altitude. The team expects to see no issues with the 9V battery life in flight. Overall, the aircraft should be the most efficient at the highest altitude because it experiences the least air resistance.

8.0 Launch and Recovery

On launch day, the payload was checked in at 5:05 AM, and the initial launch was around 7:00 AM. Samuel was the handler and recovered the payload after flight. The initial flight took two hours, and recovery took around three hours. During recovery there were no signs of damage on the panels as well as the payload itself. The payload was still running retrieval, which showed good signs. The control panels were attached to a car and charged on its way to get the payload to help compare the data of the ones on the payload. The payload launch site was at Deer Trail Elementary school and landed at (-103.178333,39.255667) east of the launch site.



Figure 9: Solar Panels After Flight

The solar panels on the payload charged up to 1.706 V in figure [9] which has shown the panels charged during flight. There were some scratches on the solar panels upon retrieving it, but none that would prove to render the flight useless.



Figure 10: Control Solar Panels

The control panels showed damage before testing but still collected data normally. While the data collected on the solar panels were higher than the control test, it showed that the panels on the payload collected enough data to make a comparison of the panels and provide a table on the results.

9.0 Results, Analysis, and Conclusions

After assessing the data of the payload, there was only one file showing that the payload lasted the entire flight. Two graphs were made -- one with all the data and the other with the acceleration on the x and y axis.

Team Hot Air hypothesized density altitude values would be similar to standardized ones, oxygen partial pressure would decrease enough to require supplemental oxygen around 12,500 ft, the aircraft would become more efficient with greater altitude, a 9V battery would be able to power the Arduino and sensors through the duration of the flight, and the solar panels would charge significantly faster at altitude than on the ground.

2nd paragraph Results from the complicated equation given by the data. COMPARE AND CONTRAST (reference previous graphs as needed)

The solar panels have different results due to shadows at the end of the flight, but the test has shown that the solar panels on the payload had worked better than the control. In figure [10], the highest the control when measured was 0.620 Volts while in Figure [9] shown that the outside 1.706 Volts which is 1.086 V difference showing that the ones on the payload worked better to a major degree. While the data from the payload showed that the outside temperature never reached -50 degree Celsius, making the test collect all data and not limiting it to -50 degrees Celsius.

3rd paragraph, did we make a more accurate data depiction to help flight operators WHAT AND WHY

Error analysis:

The flight was executed as expected, with all sensors performing minimal error, the main source of error being the efficiency of the solar panels. When the solar panels were attached to the weather balloon, the solar panels were severely scratched, reducing the efficiency of the panels by a considerable amount, resulting in data that is inaccurate to a panel that is not scratched. In the future, if the experiment was to be run again, it would be crucial to fortify the delicate nature of solar panels. This could be done by adding an overlap on the solar panels prior to launch or boxing the panels up to protect them during transport.

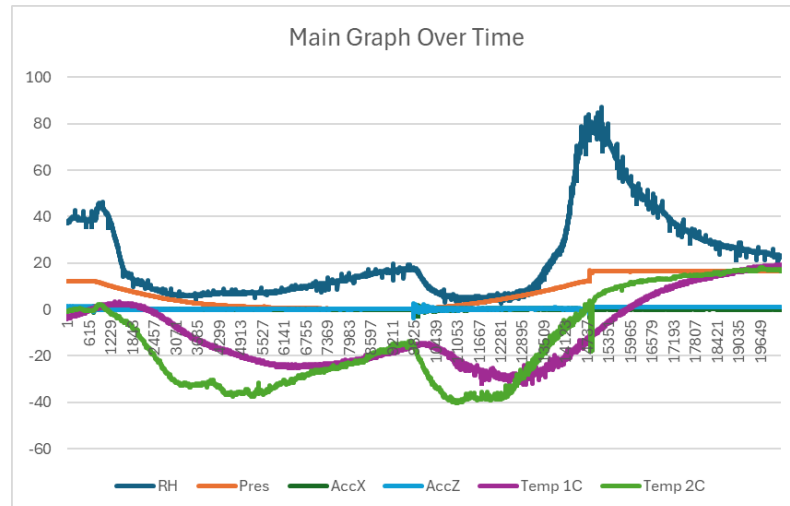


Figure 11: Collective data of the Flight

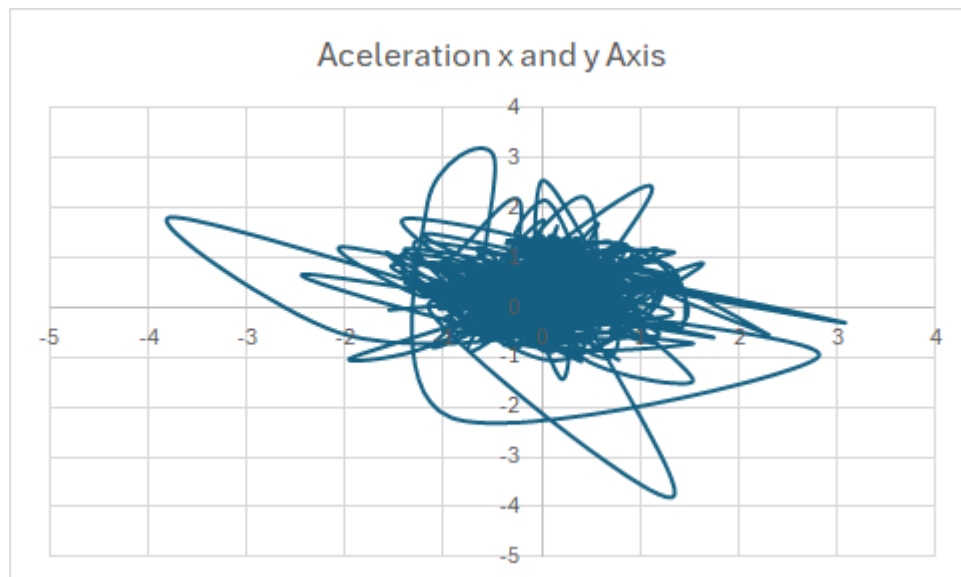


Figure 12: Acceleration Data

10.0 Ready for Flight

The payload had no major deficiencies or structural damage. The payload is ready to fly again with proper reinforcement in place. It performed as expected; the calibrated systems collected

data during the first flight. To maintain viability of the main electronic equipment, proper care must be established. This care will include storage in a dry, dark place, with ample room to ensure it stays in proper condition. Upon further use, calibration will be used to ensure sensor viability and to allow teams to reevaluate electronic maintenance. This will include replacing sensors and other electronic parts on an as needed basis. To activate the payload, attach a nine-volt battery to the system, along with a micro SD card to collect data. Once completed, flip the exterior switch to the on position and the payload is ready to collect data. The payload will last in storage for a minimum of five years, so sensor replacement is unlikely, but in the case of long-term storage, expect to replace sensors to ensure functionality of the payload.

11.0 Conclusions and Lessons Learned

Through this experiment, it was determined that data from gathered flight data is (this much) more precise and accurate compared to governmental standardized data. Payloads are essential, used in weather balloons, rocket launches, space data collection missions, and are key aspects of explorative scientific research. With science, there are many subjects that can be improved upon. Some subjects include interpersonal aspects such as leadership, worker efficiency, and some physical aspects including hardware and software troubleshooting, as well as coding. If given the chance to do this again, modernizing hardware as well as improving upon conciseness of team communication would improve the quality of the experiment, resulting in a greater quality of data.

12.0 Message to Next Year

Dear future DemoSat teams,

Students to students, the team hopes your missions are wildly successful.

The 3D printed flight tubes should make the assembly much easier. Be careful with the electronics, especially any solar panels as they are very fragile. Try and get the freeze tests in before the final week as it gets very busy with final touches. Remember nothing can leave the payload while in air.

Best of luck in aerospace,

Team Hot Air