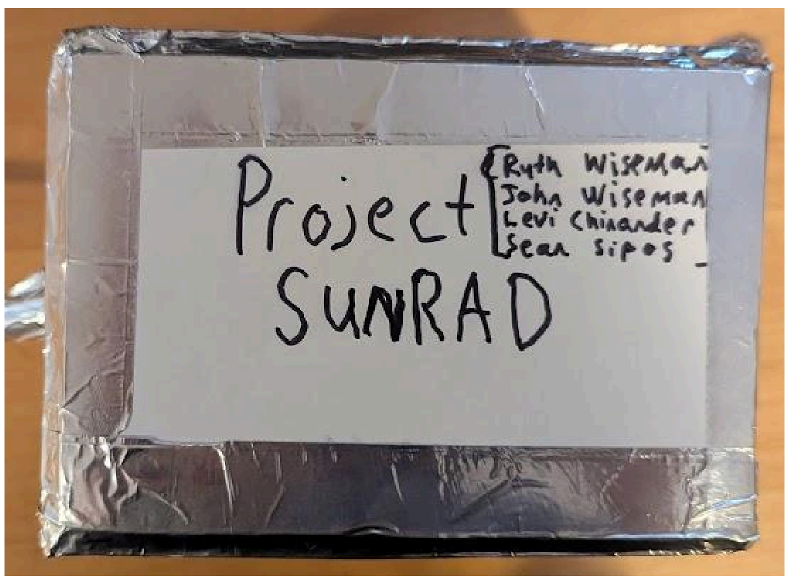
Colorado Space Grant Consortium

DETECTING RADIATION
IN EARTH'S ATMOSPHERE

Project SUNRAD



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1.0 Mission Overview

1.1 Background

It is known that radiation levels will rise with altitude. However, there is not any easily located data to prove when that change occurs. This change with altitude could have many different implications, for example, if it will affect humans and other objects. However, since the radiation levels at higher altitudes are not commonly known, we set out to measure those levels.

1.2 Methodology

In order to detect radiation, our team selected a Geiger Counter, which will detect radiation levels the higher up it travels in Earth's atmosphere. Together with a pressure sensor to find when those radiation levels change in the atmosphere, as well as internal and external temperature sensors to see if temperature has any effect on radiation levels, and a humidity sensor to measure any effects weather may have on the measured radiation. There are also three radiation detector cards to check if the radiation will be harmful to humans. One of which will be a control, and the other two will be wrapped in lead tape and carbon conductive coating respectively. This is to determine which material will prevent the most radiation.

1.3 Predicted Findings and Mission Statement

We expect that the radiation levels will increase the higher up in Earth's atmosphere they go. Our experiment sets out to find radiation data at higher levels in Earth's atmosphere as well as see if people or objects could be affected by that radiation.

The goal of Project SUNRAD is to prove that radiation levels are not harmful to humans for short periods of time, at altitudes around 100,000ft of elevation. Our mission statement is, "We hope to detect radiation in Earth's atmosphere, discover if radiation could prove harmful to humans, and find if there are any readily available materials that could prove useful to protect high-flying planes and spacecraft from radiation." Project SUNRAD attempts to account for these challenges using its onboard instruments such as a Geiger Counter, radiation cards, and other auxiliary sensors to measure radiation levels and check if there are any external factors that will affect radiation readings.

2.0 Requirements

The goal is for the payload to measure and record data for the radiation levels at different levels of the atmosphere. In order to do this, it must survive the launch as well as the landing and record data the entire time.

Level 0	1. The payload must be able to record radiation it is exposed to. 2. The payload must be able to survive the turbulent motion of the flight and landing in order to save its data. 3. The payload must be able to survive the harsh temperatures of the atmosphere. 4. The power system of the payload must be robust enough to keep all the sensors on for the duration of the flight. 5. The payload must be within the weight and cost budgets in order to be launched.
Level 1	1. To ensure quality data, our Geiger Counter and three radiation cards should be able to collect data independently without interfering with each other. 2. To ensure that the measured radiation levels are not affected by external factors, there needs to be other sensors, such as pressure, humidity, and internal and external temperature.

3.0 Design

Our experiment requires the use of a Geiger Counter to detect radiation. The other sensors are needed to make sure that the radiation levels are not affected by external factors such as humidity. The control radiation card is used to see if the radiation levels are harmful to humans, whereas the other two radiation cards will be wrapped in lead tape and a carbon conductive paint coating to see if those materials will help prevent radiation.

3.1 Requirements and Limitations

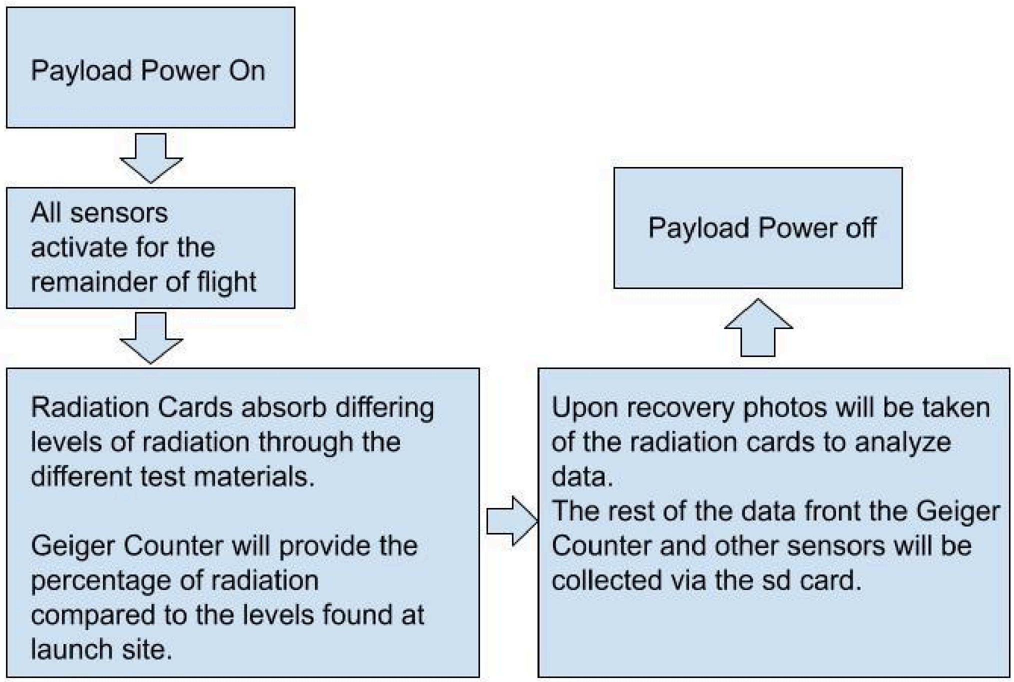
Our payload had several requirements we had to meet in order to fly.
1. There must be a flight tube running through the center of the payload.
2. The payload must be lighter than 600g.
3. The budget for the payload was $400.
4. The payload must be able to survive the duration of the flight and collect data.

3.2 Parts

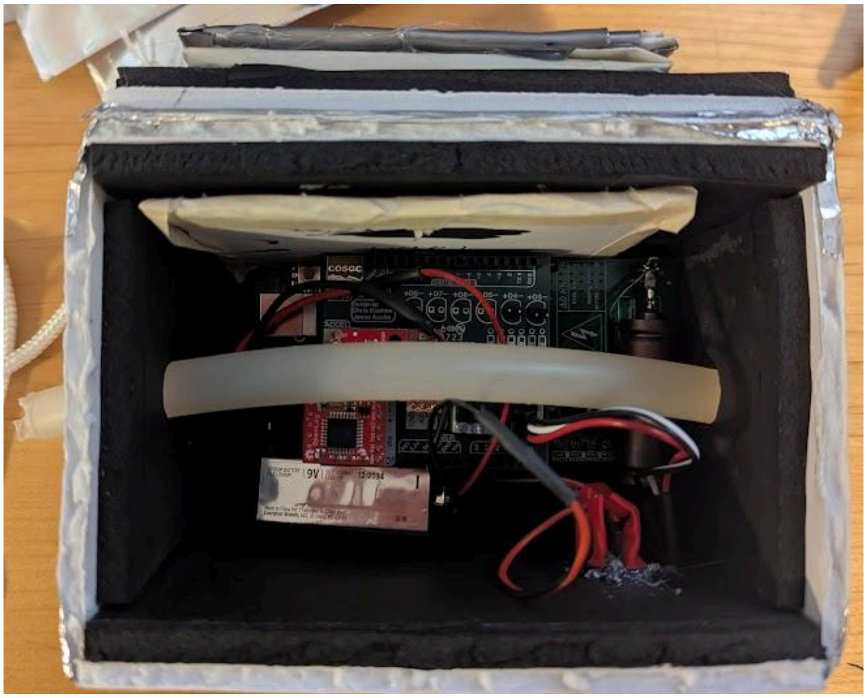
The Geiger Counter can be found on Digikey, while the Geiger Tube can be purchased from a US based manufacturer: ImagesCO Scientific Instruments. The other sensors can be found on Sparkfun. The radiation cards can be found on another US based website, My Patriot Supply, and the lead tape and carbon conductive coating can be gotten on Amazon from a US based manufacturer.

3.3 Diagrams

Concept of Operations Diagram:



There is room for the flight tube as shown by this image of the assembled payload:



Our final decision for the sensors involved using the shield with the Pressure, Humidity, and Accelerometer sensors. The Open Log was also placed on the shield. Beneath that was the Geiger Counter and Geiger Tube, and beneath that was the Arduino Uno. The carbon conductive coating paint was placed on the inside of a piece of foam board, with the radiation card put inside of it. The edges were then sealed with tape to prevent the foam board from opening during the flight. The lead tape was also placed on the inside of a piece of foam board with the radiation card inside, and then sealed with additional lead tape. The control was placed inside of a piece of foam board as well to keep it consistent.

4.0 Management

Originally, the team consisted of Ruth Wiseman and Jonathan Wiseman. Levi Chinander joined a week in, and Sean Sipos joined two weeks after that.

We met up every Tuesday and Thursday for about an hour each the majority of the semester. Parts were delayed several times, but they finally came in about 10 days before launch. We all met up for payload assembly and worked from 4-5 hours and completed assembly. Unfortunately, the Geiger Tube was delayed for another few days, and Ruth Wiseman and Jonathan Wiseman met up to attach it and get it programmed before our freeze test later that day.

4.1 Contributions

Team Lead: Ruth Wiseman

Ruth Wiseman was responsible for the organization of the project. She kept track of the schedule as well as deliverables, on top of building and soldering all of the hardware with the exception of the on and off switch and battery connector. She also worked on the case of the payload. She was in charge of communication for the team, as well as discussing ideas and asking questions with our advisor. She assisted in choosing and ordering the parts, writing the abstract, as well as writing almost all of the slideshows and presenting a fair number of the slides. She was responsible for creating the weight and cost budgets as well as keeping track of parts when they came in. She also contributed by writing a large part of the research paper.

Team Member: Jonathan Wiseman

Jonathan Wiseman programmed the entirety of the hardware and Geiger Counter using the Arduino coding interface. He also helped Ruth Wiseman with building the case of the payload and assisted her with putting the hardware together. Jonathan Wiseman also assisted in the acquisition of parts, interpreting data, as well as creating all the drawings and schematics for the slideshows, including a number of the slides. He contributed to writing the abstract. He was also responsible for calculating the energy distribution for the Payload. Jonathan Wiseman also contributed by attending meetings with our advisor and writing a significant part of the research paper.

Team Member: Levi Chinander

Levi Chinander assisted soldering the on-off power switch with Sean Sipos and finding replacement components during construction. He also worked as a payload handler, and he retrieved other payloads on launch day. He contributed to reviewing each launch document and wrote a part of the research paper. He also attended each major meeting, and helped design the experiment, researching some of the protective materials used in the launch.

Team Member: Sean Sipos

Sean Sipos helped with the soldering, soldering together the wires for the on and off switch. He also built the conductive paint envelope for one of the radiation cards. He helped bring the payload to launch, was a payload handler, and for retrieving it after and collecting the data. He contributed to the abstract. He also made sure to attend every major meeting.

4.2 Schedule

February 20th - Preliminary Design Review
February 25th - All parts ordered
March 9th - Abstract Due
March 13th - Critical Design Review
March 21st - Parts Come in
March 25th - Building
March 25rd to March 30th - Testing (Drop, Shake, Sensors, Whip, Stairs)
April 1st - Geiger Tube comes in and Freeze Test
April 2nd - Flight Readiness Review
April 5th - Launch
April 11th - Paper Due

April 24th - Presentation Slides Due
April 26th - Space Symposium Presentation

5.0 Budget

5.1 Weight

Part Name:	Weight:
Geiger Counter and Tube	130g
Arduino Uno	25g
Humidity Sensor	Negligible
Pressure Sensor	Negligible
Internal Temperature Sensor	Negligible
External Temperature Sensor	Negligible
Accelerometer	Negligible
Radiation Cards (3)	10g
Foam Board	70g
Battery	45g
Shield	Negligible
Jumper Wires	Negligible
On/Off Switch	Negligible
Lead Tape	100g
Carbon Based Grounding Paint	Negligible
Open Log	Negligible
SD card	Negligible
Altitude and Pressure Sensor	Unused
Temperature Sensor	Unused

Humidity Sensor	Unused
Total	**380g**

Note: Items with weight “Negligible” are very light and the weight is counted in the total sum

Our weight maximum was 600g, 380g is well within that perimeter.

5.2 Expenses

Part Name:	Cost:
Geiger Counter and Tube	$200
Arduino Uno	$30
Humidity Sensor	Repurposed
Pressure Sensor	Repurposed
Internal Temperature Sensor	Repurposed
External Temperature Sensor	Repurposed
Accelerometer	Repurposed
Radiation Cards (3)	$84
Foam Board	Repurposed
Battery	$0
Shield	Repurposed
Jumper Wires	Repurposed
On/Off Switch	Repurposed
Lead Tape	Self-Bought
Carbon Based Grounding Paint	Self-Bought
Open Log	Repurposed
SD card	Repurposed
Altitude and Pressure Sensor	$20 - Unused

Temperature Sensor	$7 - Unused
Humidity Sensor	$12 - Unused
Total	**$353.00**

Note: Repurposed items were left over from used kits.

Our budget limit was $400, so we are within budget.

These are the final cost and budget totals. The hardware was purchased from US companies and distributors.

5.3 Links and Suppliers

Part:	**Supplier:**	**Link:**
Geiger Counter	Digikey	https://www.digikey.com/en/products/detail/analog-devices-inc/EVAL-CN0536-ARDZ/14554876
Geiger Tube	ImagesCO Scientific Instruments	https://www.imagesco.com/geiger/geiger-counter-tubes.html
Arduino Uno	Sparkfun	https://www.sparkfun.com/arduino-uno-r3.html
Humidity Sensor	Sparkfun	Repurposed From Kit
Pressure Sensor	Sparkfun	Repurposed From Kit
Internal Temperature Sensor	Sparkfun	https://www.sparkfun.com/temperature-sensor-tmp36.html
External Temperature Sensor	Sparkfun	https://www.sparkfun.com/temperature-sensor-tmp36.html
Accelerometer	Sparkfun	Repurposed From Kit
Radiation Cards (3)	My Patriot Supply	https://www.mypatriotsupply.com/products/radtriage50-personal-radiation-dosimeter
Foam Board	Repurposed	Given from advisor
Battery		Given from advisor

Shield	Repurposed	Repurposed From Kit
Jumper Wires	Sparkfun	Repurposed From Kit
On/Off Switch	Sparkfun	https://www.sparkfun.com/rocker-switch-spst-right-angle.html
Lead Tape	Amazon	https://www.amazon.com/dp/B0C4DSW7XZ?ref_=pe_125775000_1044873430_fed_asin_title
Carbon Based Grounding Paint	Amazon	https://www.amazon.com/dp/B0D3R5KP1J?ref_=pe_125775000_1044873430_fed_asin_title
Open Log	Sparkfun	https://www.sparkfun.com/sparkfun-openlog-with-headers.html
SD card	Sparkfun	Repurposed From Kit
Altitude and Pressure Sensor (Did Not Use)	Sparkfun	https://www.sparkfun.com/sparkfun-altitude-pressure-sensor-breakout-mpl3115a2.html#
Temperature Sensor (Did Not Use)	Sparkfun	https://www.sparkfun.com/sparkfun-temperature-sensor-stts22h-qwiic.html
Humidity Sensor (Did Not Use)	Sparkfun	https://www.sparkfun.com/sparkfun-humidity-sensor-breakout-shtc3-qwiic.html

6.0 Test Plan and Results

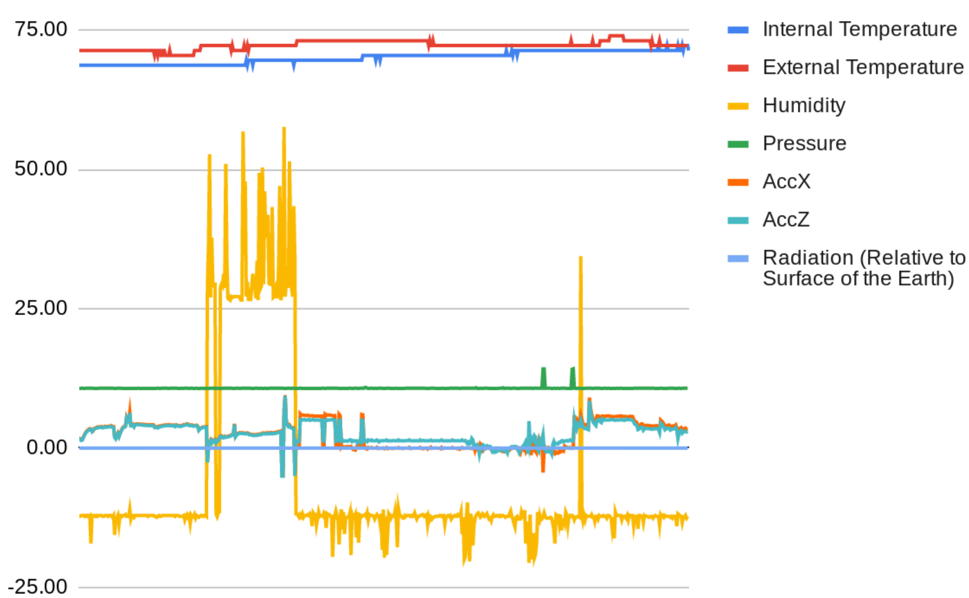
Testing the payloads functionality is vital for success because without comprehensive testing, the payload could break at certain points along its flight namely, the balloon bursting, reaching colder temperatures, and payload landing. To prepare for these conditions we subjected our payload to a multitude of tests. First, the Whip Test attempts to recreate conditions similar to when the balloon bursts and all the payloads are whipped around and possibly get tied up with other payloads. This test involves whipping the payload around to verify everything is properly secured inside the payload. Secondly, the Sensors Test verifies that all sensors are recording data properly by ensuring they respond appropriately to changes in the environment. Next, the Drop Test attempts to account for a large fall by dropping the payload from a height of about two stories. This test will hopefully ensure the payload will not be damaged after falling. After that, we subjected the payload to the Shake Test, this is a test where the payload is shaken violently to ensure there are no loose pieces and everything remains attached. Next, the Stairs Test is where the payload is launched down a flight of stairs to simulate rough landing conditions. Finally, the Freeze Test attempts to simulate the cold temperatures that the payload will be subjected to for the duration of the flight.

6.1 Testing Descriptions

To prepare our payload for launch, Project SUNRAD experienced the following:

- Whip Test: attaching a rope through the Payload and simulating the motion of the balloon bursting by whipping the payload around at high speeds.
- Sensors Test: Checking if the sensors work by manipulating the data using external factors to verify that they are functioning properly: i.e. increasing the humidity by placing the payload near a humidifier.
- Drop Test: Dropping the test from ~ 2 stories to verify the payload won't break from a fall.
- Shake Test: Shaking the Payload violently back and forth to verify parts won't come loose.
- Stars Test: Tossing the Payload down a flight of stairs to simulate landing conditions.
- Freeze Test: Placing the payload in a deep freezer for about 4 hours to ensure the payload can function at cold temperatures.

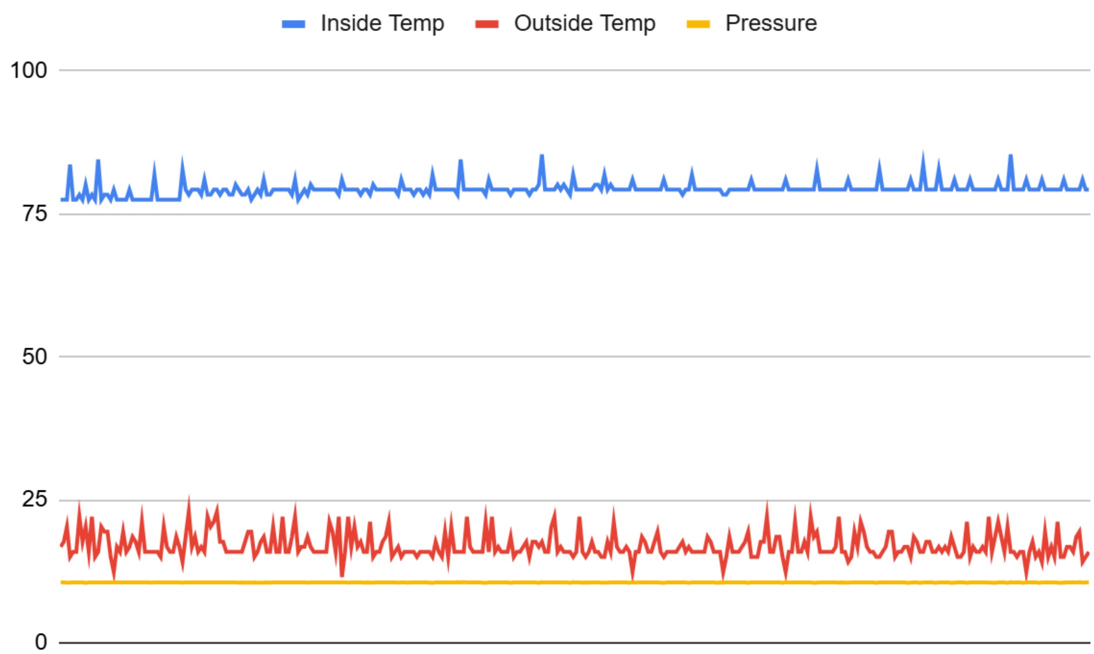
6.2 Testing Data: Whip Test, Sensors Test, Drop Test, Shake Test, and Stairs Test



The payload survived each of the tests. The data was consistent for each test and the given conditions.

6.3 Testing Data: Freeze Test

Relevant data from Freeze Test:



The Payload survived the whole duration of the freeze test and recorded the expected values for the duration of the test.

7.0 Expected Results

We expect that the data from the Geiger Counter will increase with altitude as the payload rises in the atmosphere. There might be changes or drops in it if there are outside atmospheric conditions, so we have the other sensors on there to be aware of these changes. The pressure sensor should steadily decrease the higher the payload gets. The humidity sensor should be consistent with Earth, unless the payload enters a cloud. Both temperature sensors should decrease the higher up the Payload goes into Earth's atmosphere.

Data will be stored on the SD card on the Open Log, which is, in turn, attached to the shield on top of the Geiger Counter and Arduino Uno. We have practiced accessing the data from the payload after completing the tests. This is done by uploading the data from the SD card to a spreadsheet and then graphing the spreadsheet to make the data easier to interpret.

Project SUNRAD will see if radiation will impact people and/or instruments that fly at higher altitudes, such as airplanes, and high altitude drones.

8.0 Launch and Recovery

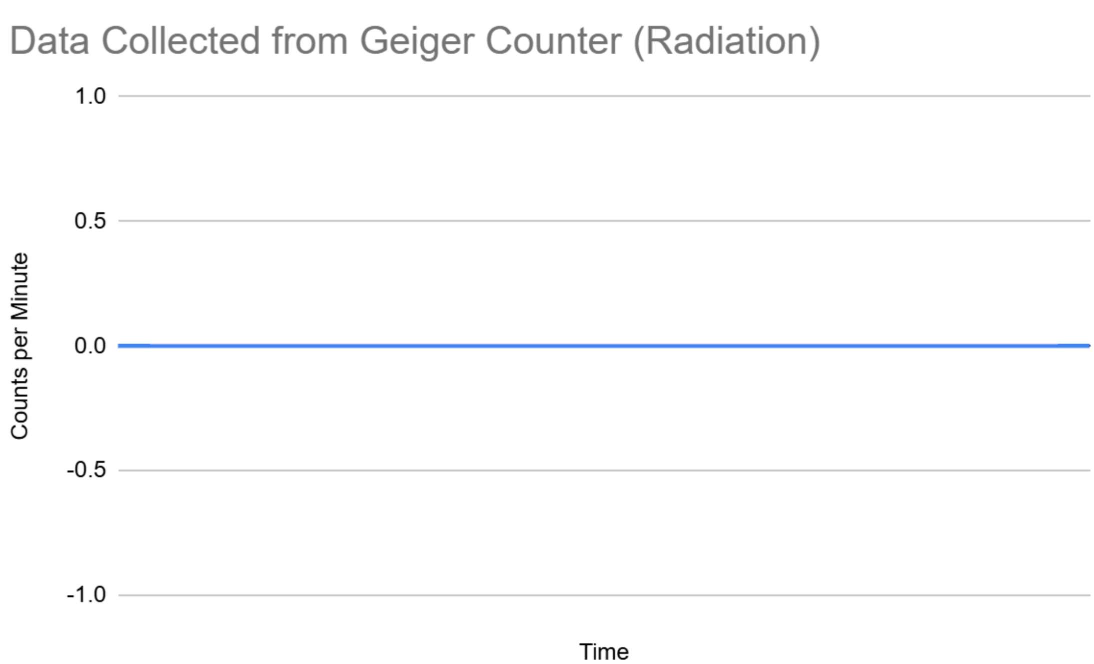
Ruth Wiseman and Jonathan Wiseman dropped the payload off with our advisor a few days before launch, since they had prior commitments and were unable to make it the day of. Sean Sipos received the payload the day before launch and traveled with our advisor to Limon Hotel to ensure that he would be able to arrive in time. He arrived at the launch site, Deer Trail Elementary, around 5:00 AM. Levi Chinander drove directly from Colorado Springs and arrived at around the same time. It was very cold. Both Levi Chinander and Sean Sipos were payload handlers. For our payload, the launch occurred at 6:43 AM. The sky was clear, with minimal clouds throughout the launch.

The launch occurred without any issues. Different launch attendants split up in different cars to collect data from different balloons, and Sean Sipos was in a vehicle following SUNRAD while Levi Chinander was sent to help collect other payloads. Our payload reached a height of 93,767 ft before bursting. The payload landed on a field. It sat on the ground while permission to enter the property was obtained. About an hour and a half after it landed, Sean Sipos was able to collect photos of the radiation cards and physically reach the payload.

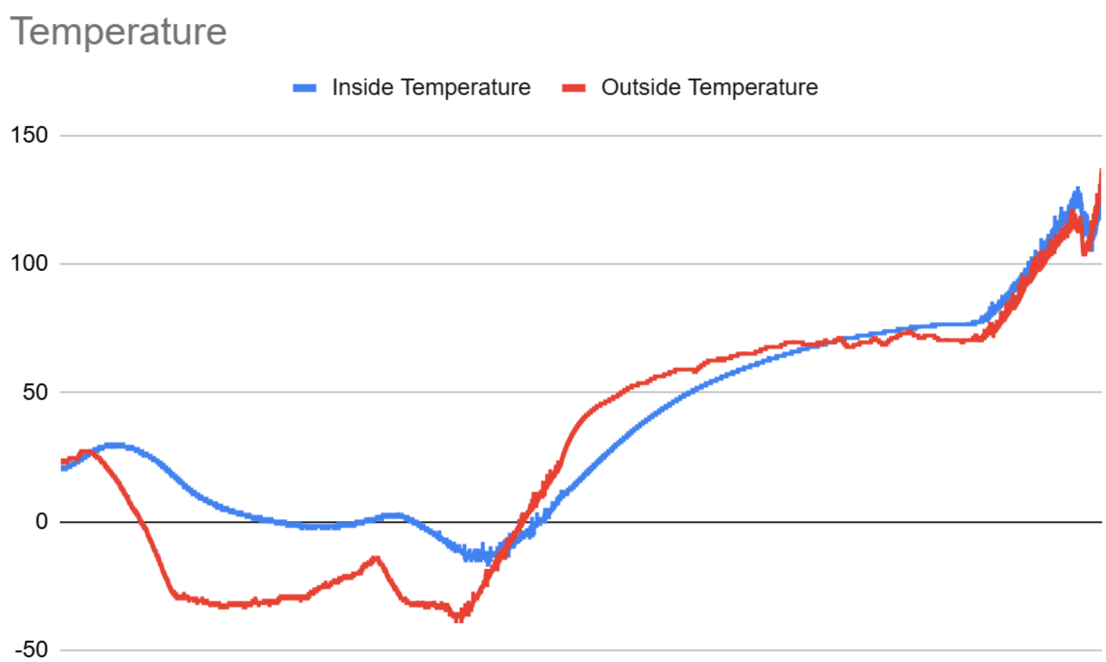
The SD card data was sent out later that day to Ruth Wiseman and Jonathan Wiseman, who analyzed it.

9.0 Results, Analysis, and Conclusions

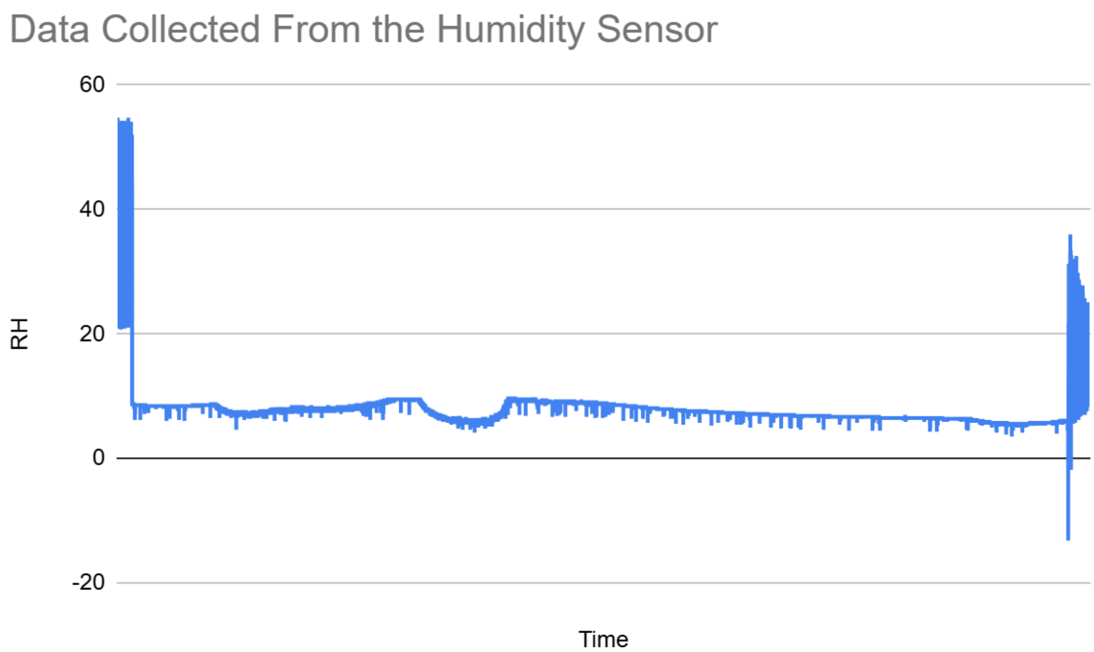
9.1 Data Graphs



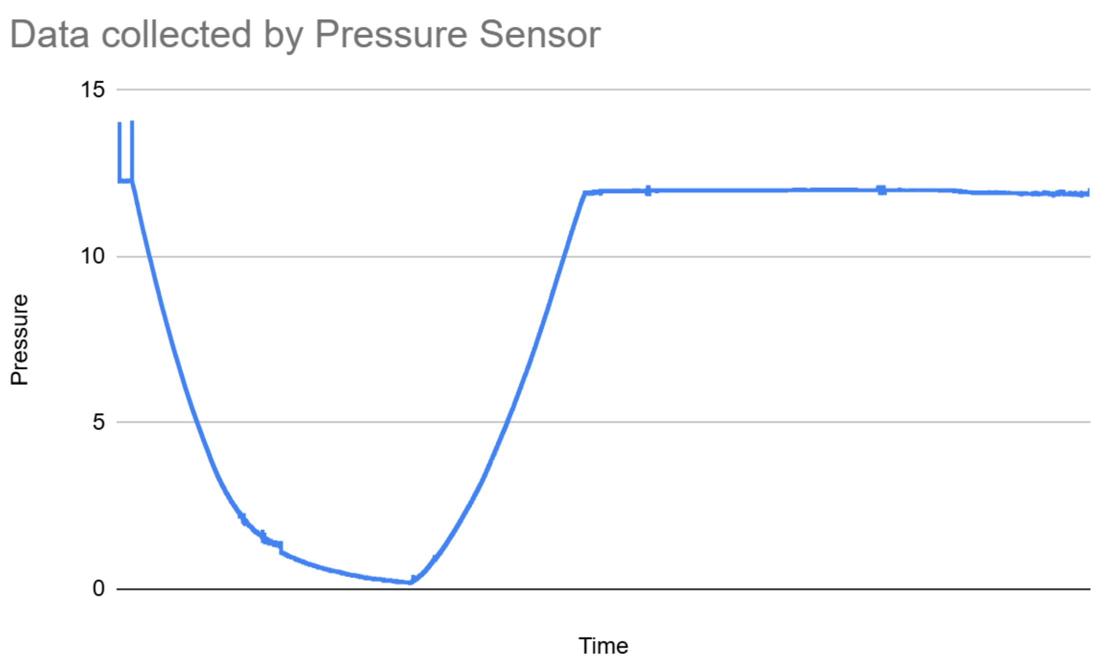
The Geiger Counter detected a negligible amount of radiation which is the one data point that was unexpected. Initially, we suspected that Project SUNRAD would detect more radiation as altitude increases. This was not the case as the Geiger Counter detected the same amount on Earth as it did the higher it got in the atmosphere. We suspect that this is because there is not enough radiation in the Ozone layer for our Geiger Counter to detect, or our Geiger Counter was not precise enough to detect the radiation. We do know that there was less than 25 mSv because the radiation cards did not pick up a detectable amount of radiation.



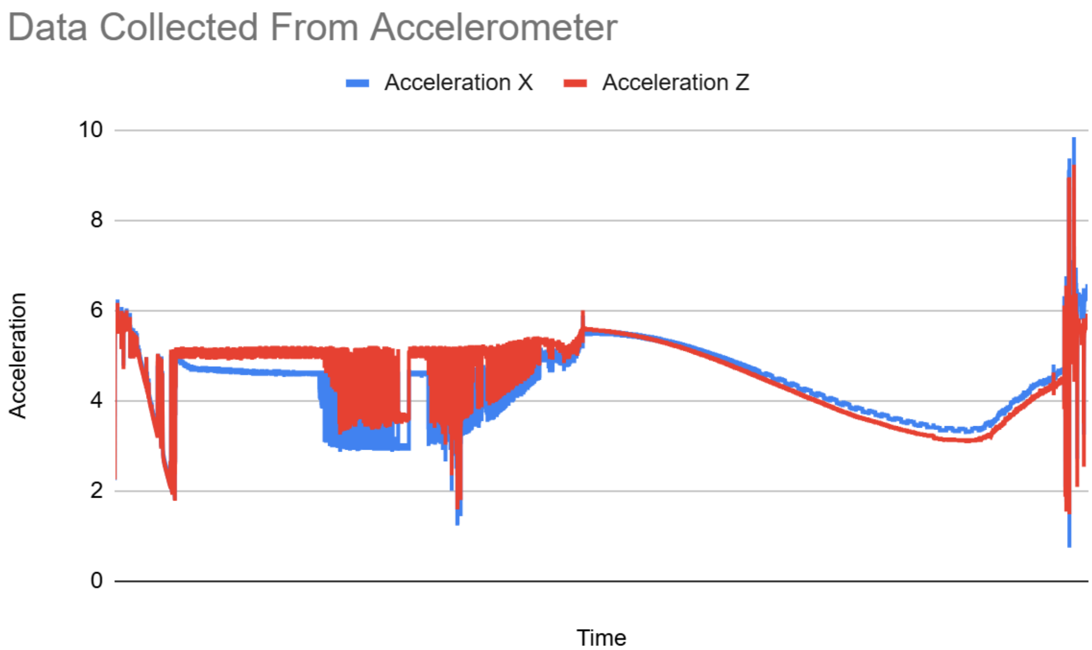
The temperature sensors recorded data as expected. We see both sensors dip as the temperature decreases with more altitude. Then as the balloon bursts and starts falling back down to Earth, the sensors properly record the increase in temperature. The reason the starting and ending temperature are different is because at the end, the sun greatly increased the temperature of the aluminum tape surrounding our box, which in turn, created a high surface temperature. Notably, our insulation was somewhat effective at keeping the inside temperature as stable as possible.



The data collected from the humidity sensor is as expected, we suspect that the increase in humidity is when being collected, human breath and handling added more moisture at the beginning and end, then is regularly seen through the majority of the flight. There is a decrease when it exits the cloud cover at the pinnacle of its flight.



The data collected by the pressure sensor is what we expected. During the payload's ascent, the pressure is decreasing, and during the descent the pressure increases. The difference between the beginning and end of the data can be explained by the change in altitude from launch site to recovery site, and by the temperature change from early morning to afternoon.



The data collected from the accelerometer makes sense as a great amount of movement is detected when the balloon bursts, as well as on the descent when all the payloads are falling. Less motion is detected at the beginning because the balloon steadily increases the altitude and as such there is less motion during this time. There is a spike in motion at the end because a large amount of motion is caused during recovery as the payload is being picked up and moved around.

9.2 Analysis

Our results seem reasonable because all abnormalities and unexpected outcomes can be accounted for. Most of the sensors display reasonable data that can be explained with the changing environmental conditions of the launch, an example of this is when the humidity sensor detected less humidity when it left the clouds towards the pinnacle of its flight. The data collected from the Geiger Counter can also be explained since there either was just not enough radiation to be recorded, or our Geiger Tube was not precise enough to measure the levels in the atmosphere.

9.3 Radiation Cards Analysis

The radiation cards did not pick up any data since they were not precise enough and there were not high enough levels of radiation. The cards state that they will not pick up less than 20 mSv of radiation, so we can conclude that there either was less radiation than that, or there was an external factor that interfered with the data since there was nothing recorded on the cards. Since there was no radiation detected by the control card, we can conclude that the carbon conductive coating and lead tape cards also have no radiation recorded because there were not high enough levels, rather than both materials successfully preventing radiation.

9.4 Conclusion

There are many different things that this experiment can be used for. Including, but not limited to, commercial flights that might need to take into consideration how much radiation is in the atmosphere so as to keep people and instruments safe from radiation as they rise through the atmosphere. This could be a factor that changes the altitude at which planes would fly. Another implication of this data could surface in rocket launches and high-altitude drones; knowing whether or not there are harmful levels of radiation could change the way people and instruments are protected during launch.

Our experiment shows that radiation in the Ozone layer is almost non-existent and does not need to be a consideration for people flying in planes, or operating drones with components that could be damaged by high amounts of radiation.

10.0 Ready for Flight (Current Payload Functionality)

A few days after recovery, our team captain was attempting to verify the functionality of the sensors and turned on the payload. Unfortunately, the payload started smoking. Our team captain immediately turned the payload off, but the damage was still done, and our payload is no longer functional. Since we no longer have a functioning payload, we do not intend to fly our payload again. We could possibly fly another payload based on what we have learned from this one, but we would need to create another one that functions properly.

11.0 Conclusions and Lessons Learned

Overall DemoSat was a great experience for us. We learned that the radiation levels beneath 94,000ft do not affect humans and other equipment.

If we could do it differently, we would have gotten a more precise Geiger Counter that could record the exact levels in Earth’s atmosphere. We believe that if the weather balloon had gone higher, we would have discovered higher levels of radiation.

We also learned to order duplicate components in case of breaks or one component is defective. The Geiger Counter suffered irreparable damage following the launch, the spare one that was ordered could be used instead if the team choses to launch again in the future.

12.0 Message to Next Year

Do lots of research on how you will assemble your parts. Our team ordered parts and assumed they would all fit together. Unfortunately, this led to the team being unable to assemble the sensors bought with the Arduino since the Arduino could not support more than two sensors, despite each sensor working individually.

Components also took longer than expected to ship due to the time required to process the order. When constructing an experiment, find compatible Arduino components that work with your experiment, and order them as quickly as possible.

We also forgot about ordering an Open Log and just assumed that the SD card would go on the Arduino. This led to confusion while building our payload because we did not know how to get the data to the SD card. We ended up using components from the payload kit for all of our other sensors, instead of trying an original method because the parts we ordered simply would not all work together with the Arduino.