MICHIGAN ENGINEERING
UNIVERSITY of MICHIGAN ■ COLLEGE of ENGINEERING

CLIMATE & SPACE SCIENCES & ENGINEERING
1005 DOW
ANN ARBOR, MI 48109

To: Dr. Aaron Ridley, Engineering Instructor
Dr. Alan Hogg, Technical Communication Instructor
Dr. Karen Springsteen, Technical Communication Instructor

From: Ian Fiorini, Engineer in Training
Isabel Holtan, Engineer in Training
Shannon Lau, Engineer in Training
Ryan Parsons, Engineer in Training
Venkata Yadati, Engineer in Training

Subject: The Effect of Altitude on Atmospheric Ultraviolet Index Values

Date: April 26, 2019

FOREWORD

The Undergraduate Forecasting Organization set out to determine the rate at which an average person could be sunburned at a given altitude. This offers a stronger understanding of how UV rays affect people at varying altitudes, such as residents of higher altitude regions. For a high-altitude balloon journey, we designed a printed circuit board to power a multitude of sensors, encased in a payload structure to meet strict flight regulations and protect our hardware. This report contains our payload design, mass, power, and data budgets as well as our rigorous testing process for a fully operative payload on launch day. Numerous figures and graphs summarize our data collection, followed by a thorough analysis interpreting their significance in regards to the UV Index values at varying altitudes on Earth.

SUMMARY

Our team found that the Ultraviolet Index tends to increase as altitude increases, until the balloon reached approximately 10 km above the ground. At this point, the UV Index readings decreased from 5 to 1. The UV Index stayed at this level until the balloon popped and started its descent back to the ground, when the UV Index increased to 5 again. This phenomenon could be explained by our balloon enlarging during the flight, increased wind speed causing payload movement, and changing atmospheric temperatures affecting our sensors. We believe that the UV Index should continue to increase consistently with altitude, but our data's trend conflicts with this hypothesis. From the UV Index data collected, we determined that it would take approximately 60 minutes to get sunburned when under 2 km altitude, and 45 minutes when between 2 km and 10 km. We recommend further sensor testing and balloon launches to determine the reason our data had an unexpected curve at 10 km, and to launch higher altitude balloons to further map the UV Index of the atmosphere.

INTRODUCTION

Our team, the Undergraduate Forecasting Organization (UFO), worked for four months to design, construct, test, and launch a payload attached to a high-altitude weather balloon. Our system features sensors to collect temperature, pressure, humidity, UV Index, and GPS data for calculation and analysis; each component was thoroughly tested and included to help us achieve our science goal.

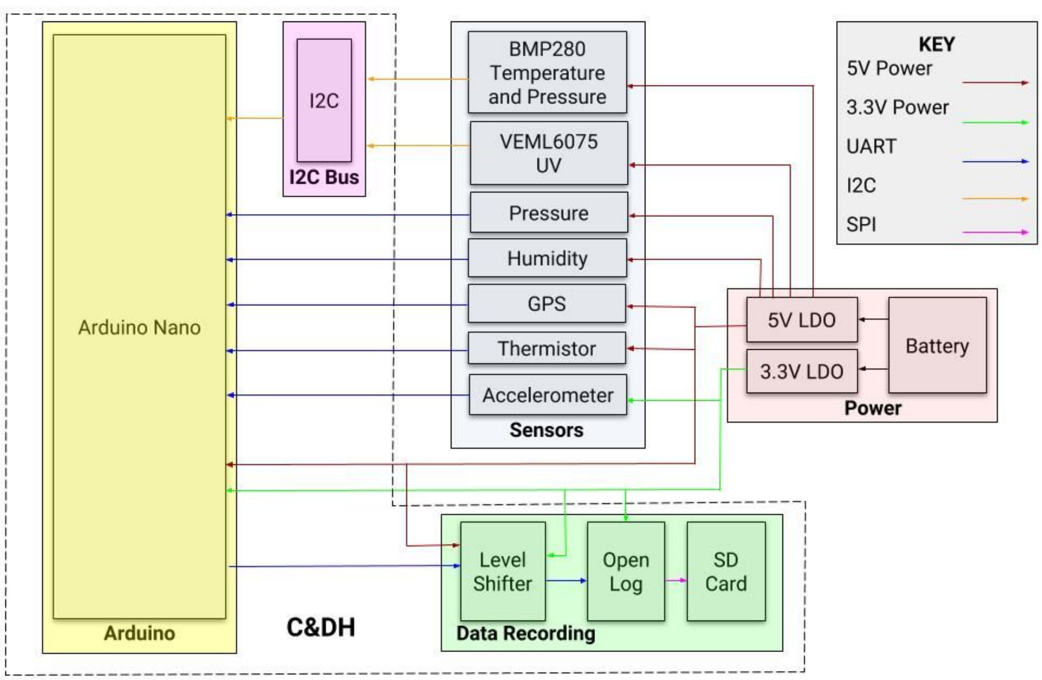
Mission

We aim to observe how UV Index in the atmosphere changes with altitude. To demonstrate this tangibly, we present the data as a relationship with the duration of time it takes for someone to get sunburnt.

METHODOLOGY

The electrical system is designed to be a mobile laboratory that gathers data from sensors, communicates this information to an Arduino Nano, and then records it on an SD card through OpenLog, a data logger. These sensors measure pressure, humidity, temperature, acceleration, and GPS location. Two additional sensors specifically help to achieve our science goal: a VEML 6075 measures UVA, UVB, and the UV Index, and a BMP 280 is a secondary measurement of temperature, pressure, and altitude. The complete integrated system is illustrated in Figure 1.

Figure 1: System level block diagram of different subsystems interfacing together



The Arduino Nano communicates with most of the sensors via UART; however, the GPS sensor communicates digitally, and the VEML 6075 and BMP 280 communicate using the I^2C communication protocol. I^2C allows both sensors to be connected to the Arduino Nano amidst the limited number of analog pins. The existing I^2C libraries also assist in interfacing with the sensors.

The whole system is powered through a 7.4V battery that is split into 5V and 3.3V via two LDOs. Most sensors require 5V, with the exception of the accelerometer and OpenLog, which utilize 3.3V of power. The level shifter appropriately translates the 5V signal from the Arduino to a 3.3V signal to the necessary sensors.

BUDGETS

This section details the constraints we had for the mass, data, and power budgets and how the decisions we made to remain within these constraints.

Mass Budget

As weight is a significant factor in launching our payload, we began our design with a mass budget, shown in Figure 2, that limits us to a maximum weight of 1 lb. This includes the mass of our Arduino, added sensors, the circuit board itself, and the payload structure, Mike Wazowski, that will be further elaborated upon in the Design portion of this report. Note that with our initial mass budget, we had a slight margin of flexibility (17.92%) that would later be to our benefit when we wanted to add additional components to our payload.

Figure 2: Original mass budget, prior to testing and final design

Component	Weight (oz)	Component	Weight (oz)
Arduino	0.247	PCB	1.200
Thermistor	0.003	Mike Wazowski	8.100
Accelerometer	0.035	Wiring	0.200
Humidity	0.018	Battery	3.250
Pressure	0.071		
VEML 6075	0.028		
BMP 280	0.046	Total (oz)	13.568
Open Log	0.035	Total (lbs)	0.848
Level Shifter	0.035	Max Weight (lbs)	1.000
GPS	0.300	Margin (%)	17.92%

After consulting with others during our Preliminary Design Review and through testing our payload, we made specific adjustments that altered our mass budget. Figure 3 displays these changes, mainly in the addition of payload attachments and modifications to Mike Wazowski. The design was slightly altered in how it would be connected to the high altitude balloon; by adding a carabiner and a mesh bag, this added 3.05 oz to our total mass. To compensate, we decreased the mass of our Mike Wazowski payload, also detailed later in the report. Having an initially flexible mass budget gave us the opportunity to make adjustments as needed and ensured that we did not have to sacrifice other integral parts.

Figure 3: Our payload final mass closely fits inside the budget with a 0.26% margin

Component	Weight (oz)	Component	Weight (oz)
Arduino	0.247	PCB	1.200
Thermistor	0.003	Mike Wazowski	7.240
Accelerometer	0.035	Wiring	0.400
Humidity	0.018	Battery	3.250
Pressure	0.071	Payload Attachments	3.050
VEML 6075	0.028		
BMP 280	0.046	Total (oz)	15.958
Open Log	0.035	Total (lbs)	0.997
Level Shifter	0.035	Max Weight (lbs)	1.000
GPS	0.300	Margin (%)	0.26%

Data Budget

Our team also made conscious decisions on how frequently we wanted to collect data from each of our sensors, as shown in Figure 4. We have a total storage capacity on our memory card that we needed to adhere to effectively get all the data from the flight. Because our mission focuses on how the UV Index changes with altitude, our essential, raw data was UV Index, temperature, and pressure. Therefore, we drew data from the VEML 6075, BMP 280, and our pressure sensor most frequently at each second, while the remaining data was collected less frequently. Overall, we had a very large margin for data because of our substantial card capacity.

Figure 4: The data budget with a flexible 2392602.26% margin

Component	Bits Per Measurement	Measurements Per Minute	Minutes Per Flight	Kilobytes Per Flight	Contingency (%)	Grand Total (Kilobytes)
GPS	200	12	150	45.0	5%	47.25
Thermistor	56	30	150	31.5	10%	34.65
Accelerometer	136	30	150	76.5	10%	84.15
Humidity	48	30	150	27.0	10%	29.70
Pressure	64	60	150	72.0	10%	79.20
VEML 6075	16	60	150	18.0	10%	19.80
BMP 280	32	60	150	36.0	10%	39.60
Total						334.35
Card Capacity						8,000,000
Margin (%)						2392602.26%

Power Budget

Our payload needs to be powered all the way through the flight for complete data collection. With a battery capacity of 22000 mAh, we accounted for all the power consumed by our Arduino, sensors, and power regulators. With a 1259.87% we found our payload to be well-powered, ultimately improving our confidence in the payload power system.

Figure 5: The power budget with a 1259.87% margin

Component	Current (Amps)	Voltage (V)	Power (W)	Duty Cycle (%)	Total Power (W)	Contingency (%)	Grand Total (W)
Arduino	0.01900	5.0	0.0950	100	0.0950	5.00%	0.0998
GPS	0.02500	5.0	0.1250	100	0.1250	5.00%	0.1313
Thermistor	0.00250	5.0	0.0125	100	0.0125	10.00%	0.0138
Accelerometer	0.00035	3.3	0.0012	100	0.0012	5.00%	0.0012
Humidity	0.00050	5.0	0.0025	100	0.0025	5.00%	0.0026
Pressure	0.00700	5.0	0.0350	100	0.0350	5.00%	0.0368
VEML 6075	0.00048	5.0	0.0024	100	0.0024	5.00%	0.0025
BMP 280	0.00072	5.0	0.0036	100	0.0036	5.00%	0.0038
Open Log	0.00600	3.3	0.0198	100	0.0198	5.00%	0.0208
LM1117	0.00635	4.1	0.0260	100	0.0260	5.00%	0.0273
LM7805	0.05520	2.4	0.1325	100	0.1325	5.00%	0.1391

Total (W)	0.4789
Time to Run (hours)	2.5000
Energy Used (WH)	1.1972
Energy Used (mAh)	161.7799
Battery Capacity(mAh)	2200.0000
Margin	1259.87%

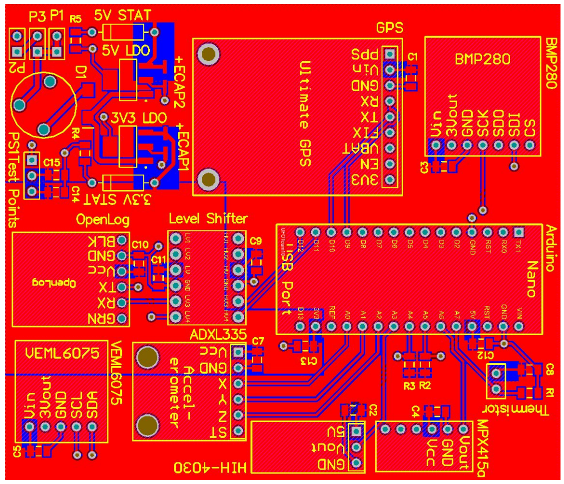
DESIGN

Our design features the printed circuit board, on which our sensors and other electronics are mounted, as well as the outer payload structure that housed our board. Our payload when through multiple design modifications to achieve its strongest build quality and flight performance.

Printed Circuit Board

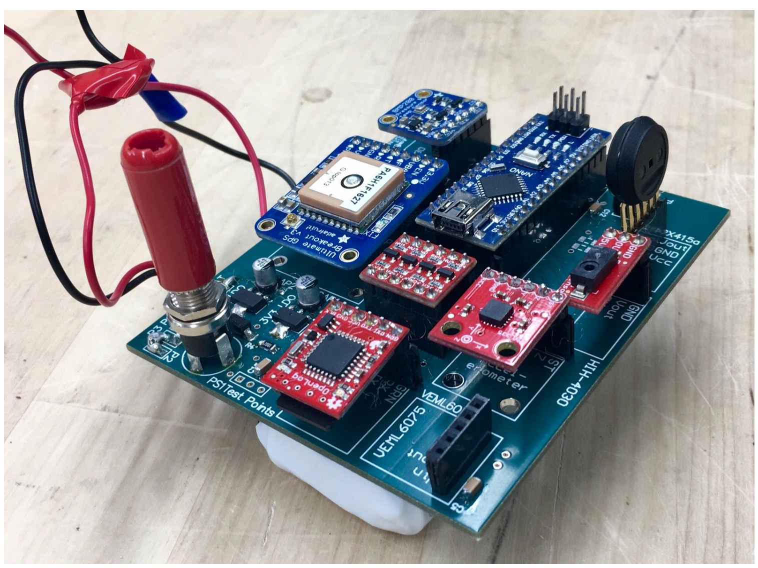
The printed circuit board (PCB) was designed using Altium, with different subsystems grouped together to reduce routing (Figure 6). Additionally, 5V and 3.3V polygons are on the top layer along with a ground polygon on the bottom layer to reduce routing. The final dimensions of the PCB are 3” x 3.5”, making the PCB easy to accommodate within the payload.

Figure 6: Altium schematic including polygons



The PCB was assembled incrementally. The battery components were first soldered on and tested for continuity. This was followed by soldering female connectors to every through-hole, on which our sensors would be mounted, to ensure that we could use interchangeable components on our PCB. Thereafter, we mounted and tested each sensor one-by-one. Finally, the battery was connected to the PCB using a “Y” wire as its recharging mechanism. The final PCB is shown below in Figure 7. The thermistor and VEML 6075 are connected to the female headers through wires and therefore are not shown below.

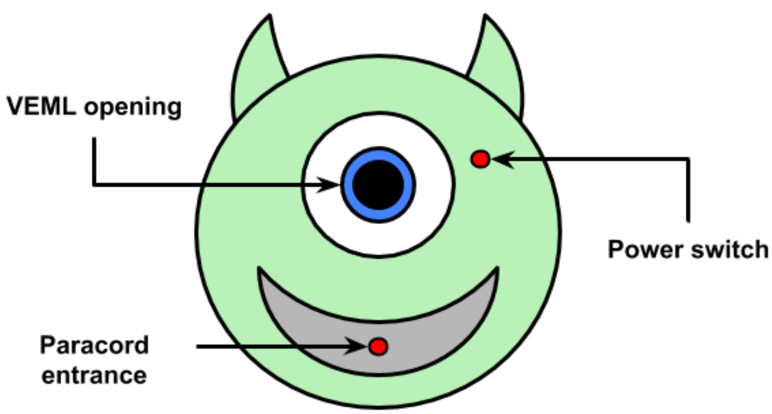
Figure 7: Complete, soldered PCB with battery



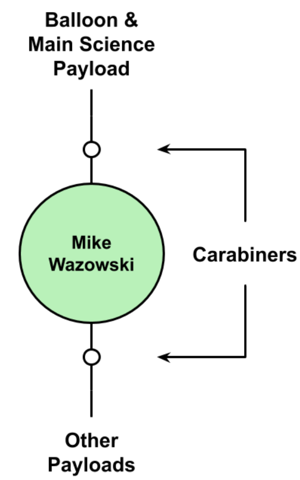
Original Payload Design

We chose a plush Mike Wazowski as our payload package. With the dense internal stuffing, it (or he) provides significant insulation and shock resistance. For our initial design, we planned to cut an incision on the top of Mike to sew a zipper in, creating a compartment well insulated to store the PCB and battery. The eye would also be removed to create a hole for light to reach the interior of Mike and allows the VEML 6075 to make accurate UV Index readings. Another hole would be created a few inches to the right of the eye as well, where the remove-before-flight pin would be accessible as a power-on switch before launch. We originally prepared for a Type 2 connection, with a hole at the top and bottom of Mike for a paracord to run through, and carabiners on each to connect to other payloads (Figure 8b).

Figure 8: Original design with (a) Mike Wazowski's front side and (b) the Type 2 connection



(a)

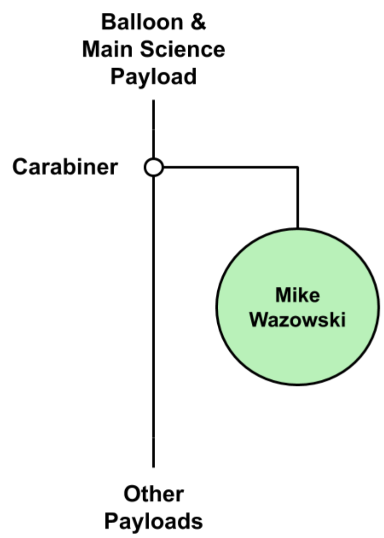


(b)

Final Payload Design

After deliberation and consulting with other teams, we made a few adjustments to the design of our payload. Because there was a possibility of the paracord ripping through the payload fabric while in flight, we decided to switch to a Type 1 connection, as shown in Figure 9 below. This consisted of placing Mike in a makeshift mesh bag cinched at the top with a pin. The bag, being too deep for our purposes, was cut at the bottom and re-knotted to remove excess mass from our payload. We concluded that this design was not only safer for our payload, but also far easier to execute.

Figure 9: Revised connection design to Type 1, which shows that our payload is externally attached to the payload train using a carabiner



In the final design of the payload, we mounted the VEML and thermistor on our payload surface, running wires from the sensors to the PCB. This allowed the VEML to be exposed to light and the thermistor to make temperature measurements without being affected by the insulation. This modified design made for a more secure way to get accurate measurements while maintaining the payload's structural integrity as much as possible. The zipper to access the interior compartment was kept from the original design (Figure 10).

To adjust to the mass additions from these modified components, our team eliminated weight from Mike, removing stuffing and his limbs. We also sewed his sides tighter to adjust for the lost mass and maintain his density for insulation. Ultimately, our payload proved to be straightforward to modify while maintaining insulative and shock protective qualities.

Figure 10: Finished payload, with (a) zipper compartment and (b) VEML 6075 & thermistor mounted externally

TESTING

Sensor Test

While assembling the PCB, sensor tests were conducted one at a time. This consisted of uploading sensor-specific Arduino code, reading data from the sensor, and writing it to storage through OpenLog, therefore ensuring that individual elements were functioning. All sensors passed this test on the first attempt. Afterwards, the sensors were linearly calibrated with two measurements in different conditions. Altogether, the system ran successfully.

Benchtop Test

The benchtop test proves that the payload can run and collect reliable data for a duration of two hours in standard conditions without stopping. This test primarily checks the robustness of our power system and program throughout the ideal time of our launch. We combined this with the Blue Bus test, as described later, and passed the test, successfully obtaining data from all of our sensors. After moving our VEML to the exterior of our payload, we performed this test again and retrieved accurate data.

Cold Test

The cold test ensures that the payload is insulated and that the PCB continues to function at temperatures down to -60°C. The test consists of placing the payload in an icebox for two hours through which the sensors should continue to operate and write data to OpenLog. We performed the cold test twice with successful results both times, the first time was with the VEML 6075 and thermistor inside the payload, then the second with the sensors on the exterior. Both tests passed with accurate measurements being taken by internal and external sensors.

Shock Test

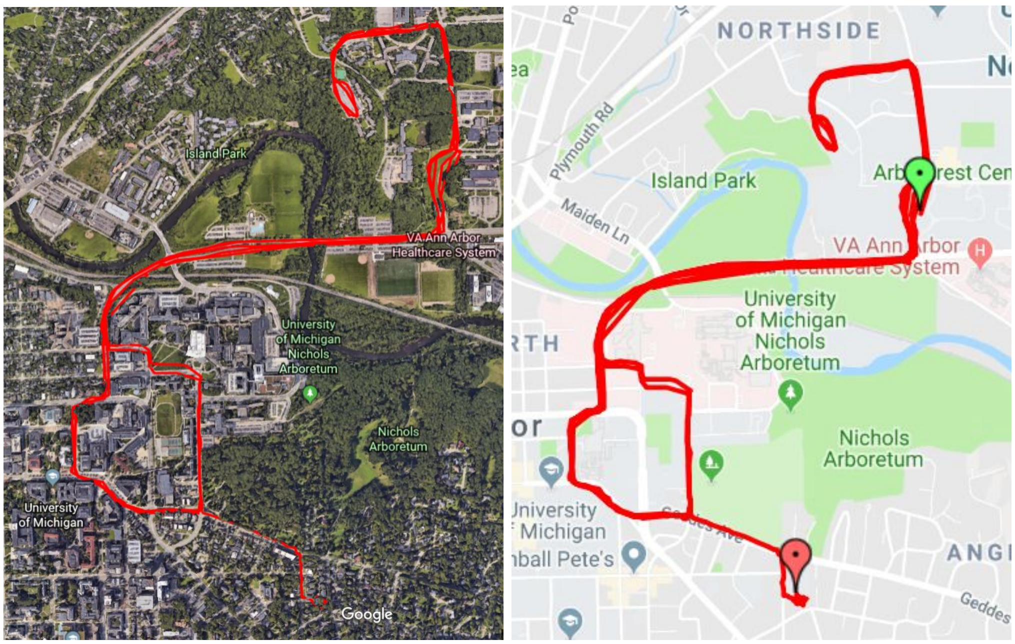
The shock test ensures that the payload can protect the PCB from up to 3 g's of force. During flight, the payload encounters shock with wind turbulence, landing, and impact in other miscellaneous conditions. To test for these conditions, the payload containing the PCB was rolled and thrown down the stairs while powered on. When checking our data following the impact, we found that our system experienced an acceleration slightly more than 3 g’s and recorded data with the shock.

The payload was additionally swung around in a circle by the mesh bag to create significant centripetal force, confirming that the knot on the bottom of the mesh bag could withstand large amounts of force. The payload recorded all data during this portion of testing and survived this test with no damage done to it.

Blue Bus Test

The Blue Bus test assesses whether GPS can record accurate coordinates for an extended period of time, vital for obtaining information on our payload location during flight. This test involved riding the Bursley-Baits bus route for 2 hours, or about three complete loops, to achieve an accurately mapped out route. Two of the team members switched off riding the bus, with the final person walked to Oxford Housing, for a total of 2.5 hours (Figure 11). After parsing out the GPGGA strings and plotting on Google Maps, the GPS was confirmed to be working and passed the Blue Bus test successfully on the first attempt.

Figure 11: Mike Wazowski's route during the Blue Bus test, from Pierpont Commons to Oxford Housing

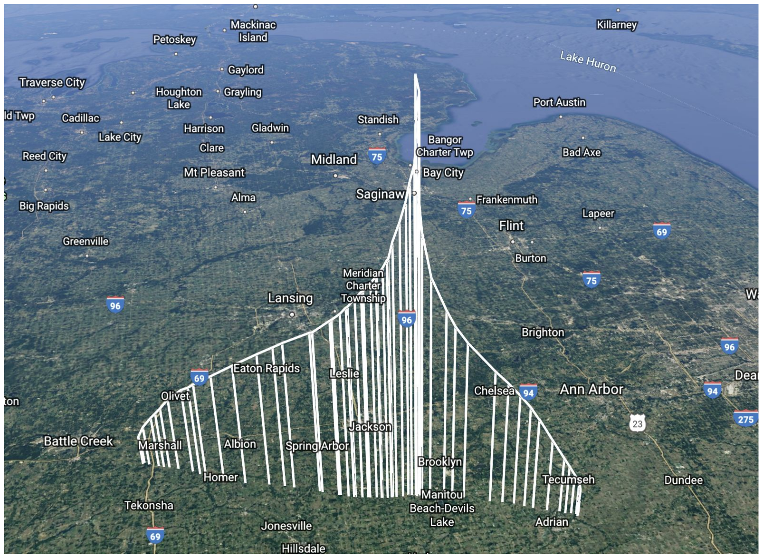


LAUNCH OVERVIEW

Our team performed our launch on April 10, 2019 from Crystal Farms in Marshall, Michigan. At the launchsite, we began by preparing our helium balloon, inflating it under a tarp for approximately 15 minutes. During this time, our team also set up our payload as a Type 1 connection along the paracord that would be attached to the balloon. Once we released the balloon, we utilized the GPS trackers to follow the predicted flight path and meet the payload at the landing site.

At a peak altitude of 26822.4 meters, the balloon burst and our payload began its descent, eventually landing in a field east of Adrian, Michigan (Figure 12). Overall, our payload was in flight for a total of 89 minutes, taking off at 11:35am and touching down at 1:04pm.

Figure 12: The flight path of our payload travelling across Michigan (Data retrieved from SPACE 584 students)



Just minutes before launch, we realized our OpenLog sensor could not successfully write to the SD card on board, are the sensor's LED was not blinking. We tried troubleshooting what we could—re-inserting the SD card, restarting our PCB, and checking the connection between our sensors and the board—but ultimately, we were unable to find the cause of the error. Because of our limited time, we let it go, proceeded with the launch, and hoped for the best. When the payload touched back down, we observed that the sensor LED was still off; when we checked the SD card, only a part of the header of the first line was written. The rest of the file was blank.

Determining the source of this error was difficult as this problem never occurred in our previous testing, and we did not alter the system program prior to launch. The day after the launch, our team ran additional tests in an attempt to find a bug in our code or an indication of malfunction in our OpenLog sensor. Ultimately, we found the error to be a loose wire connection between the VEML 6075 and the circuit board. When the code ran `veml.begin()` as part of our error-checking system, the entire program crashed, and any subsequent calls were ignored. Our rigorous testing process accounted well for the impact and cold temperatures that our payload had to withstand, yet it was not able to factor in a faulty wire connection that occurred between our testing period and launch day. We fortunately had permission from Seal Team 9, whose payload was also on our balloon, to use their data and proceed with processing and analysis.

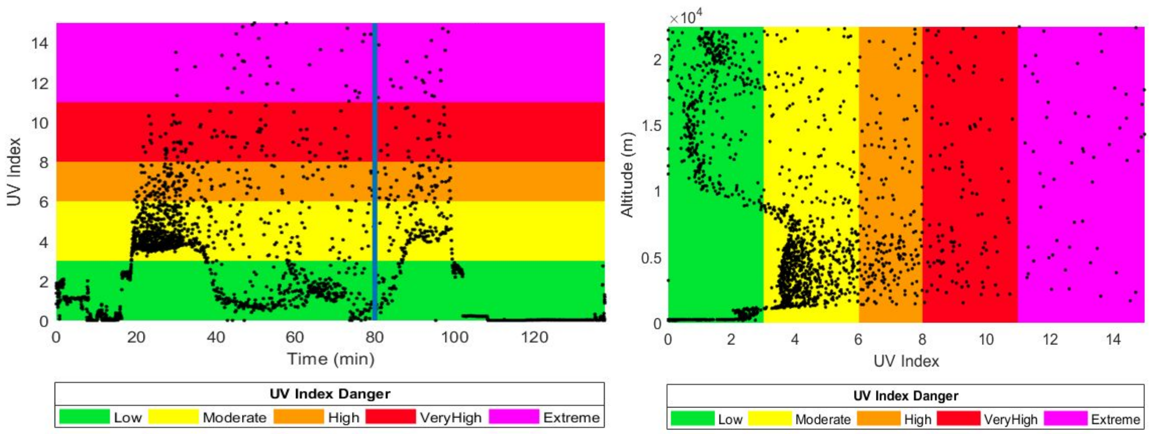
DATA AND ANALYSIS

This section will cover the data we received from SEAL Team 9 because our payload failed to collect data due to a wire malfunction. Our team focused on analyzing the UV Index through time and altitude, while also comparing our odd UV trend with other data collected to observe how other factors could affect the accuracy of the UV Index data.

Data

At the beginning of our flight, the measured UV Index began at approximately 1. As our payload ascended, the UV Index measurement increased to about 4. However, at about 40 minutes into the journey, or 10 km into the air, the UV Index levels drastically drop back down to 1. The measurements remained steadily low until the 80-minute mark, when the balloon popped and the payload began its descent. The UV Index rose again to 4, until it landed, and the UV Index went back down to 1. This is displayed in Figures 13a and 13b.

Figure 13: UV Index Over Weather Balloon Flight, vs. (a) Time and (b) Altitude (Data From SEAL TEAM 9)



(a) **(b)**

Analysis

To answer our science goal, we analyzed the UV Index values detected from the VEML 6075 by altitude as shown in Figure 13. It is clear that the UV Index increases as the balloon ascends until it reaches a UV Index of 4, and it will remain near this value until it enters the stratosphere. Generally, UV rays produced by the sun will be lower in the troposphere (below 10 km) than the stratosphere (10 - 50 km) because as the sunlight travels longer, the UV rays will reflect off more particles in the air, thus reducing UV ray intensity, yet this contradicts the trend of our data (Figure 13b). The UV values on the trend of the data could be due to varying cloud cover, balloon shadow, payload movement, and sensor restrictions that vary the amounts of sunlight to reach the sensor. These factors can also explain the many outliers outside the trend of the data.

Cloud Cover

Since the balloon has surpassed most clouds by 10 km, and the variability of the UV values outside the trend remains consistent, this variability could be caused by the shifting and rotating payload throughout the journey (Appendix A, Figure A1). Unfortunately, we were unable to calibrate the humidity sensor data we received from the other teams, and therefore could not conclude when our payload entered or exited clouds throughout its flight. Even with valid humidity data, it would still be difficult to determine when clouds high above the payload blocked the sunlight, since the payload itself would not be inside the cloud.

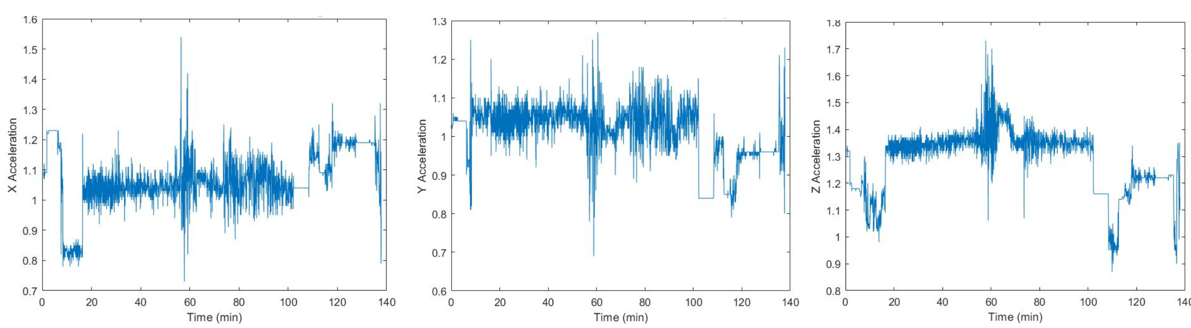
Balloon Shadow

Since the launch occurred around noon, the sun was directly overhead of the balloon and the ensuing shadow would block direct sunlight from reaching the VEML 6075. This effect was maximized at higher altitudes when the balloon's radius reached ten meters, thus, blocking all but the reflected sunlight of the sky from reaching the sensor. This is shown in Figure 13a, at 40 minutes, when the UV levels drastically drop from approximately 4 to 1 UV. Despite being at high altitudes, the UV Index values drop because of the balloon's shadow on the sensor. When the balloon burst and the sensor was exposed to direct sunlight again.

Payload Motion

The miscellaneous data points that do not lie with the trend of the data could be due to the payloads motion during the flight. As shown in the graphs below, the payload experienced almost constant acceleration in the x-, y-, and z-directions throughout the flight, turning the payload, and preventing the VEML 6075 from receiving direct sunlight at these times. It is possible that when the balloon entered the stratosphere, the increased wind from the jetstreams shifted the payload and caused the sensor to report lower values. In Figure 14, the accelerations of all three axes were highest from 60 minutes to 80 minutes, when the UV Index sensor reported low values.

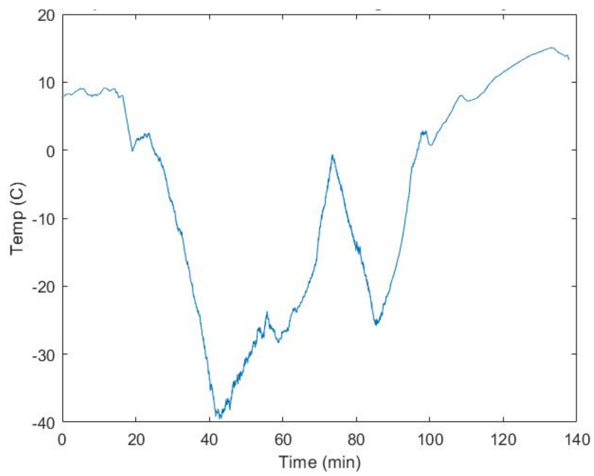
Figure 14: Acceleration in the X-, Y-, and Z-Axis Over Weather Balloon Flight (Data From SEAL TEAM 9)



Sensor Restrictions

It is also hypothesized that the VEML 6075 has temperature restrictions that prevented it from obtaining accurate measurements. According to the VEML specification sheet, the sensor operates at a minimum temperature of -40°C; approaching this point, the sensor cannot be relied on for accurate data collection. Just before the 40-minute mark in Figure 15, the temperature dips towards this threshold value. At this time in Figure 13a, the UV Index also dropped significantly. It is possible that reaching this low temperature caused the VEML sensor to malfunction for a period of time.

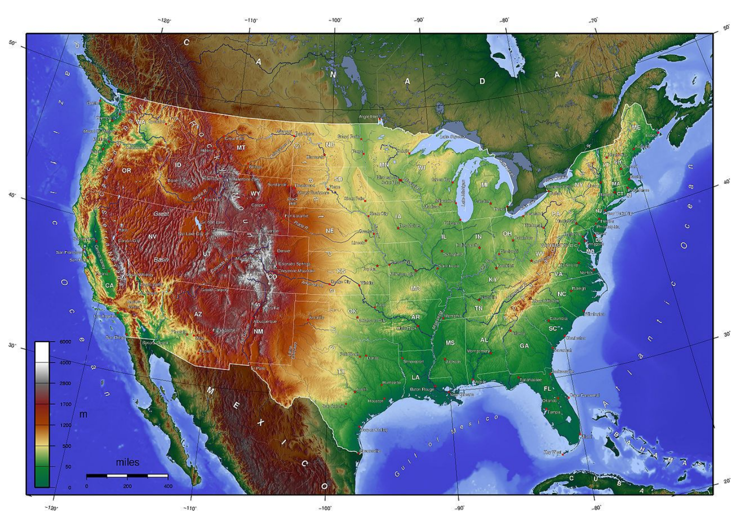
Figure 15: Temperature during the flight, where the payload achieves a minimum temperature of -40°C



Effect of Altitude on Sunburn Time

For this launch day and time, as shown in Figure 13b, the UV Index between the surface and 2 km is in the low range of 1-2. However, the UV Index is between values of 4 - 6 once the balloon rises past 2 km off the ground. This is still in the troposphere, but this altitude could be achieved by going to any of the western states such as Colorado that have high altitude mountains as shown in Figure 15 below. These mountains reach a maximum altitude of 4.4 km at the peak, but there are still numerous locations on these mountain ranges that are consistently 2 km tall as shown in red in Figure 18. Based on our data, living in these high altitude states would expose you to 2-3 times more UV rays than living in Michigan. As a result, the people living in these high altitude states would be sunburned within 45 minutes instead of 60 minutes in direct sunlight (Appendix A2).

Figure 15: Topographical map of the United States showing different altitudes



CONCLUSION

Our mission was to observe how UV Index in the atmosphere changes with altitude, and to present it as a relationship with the duration of time it takes for someone to get sunburnt.

Despite several disrupting factors in our system above 10 km, we were able to accomplish our mission up to that point. We determined that it would take approximately 60 minutes to get sunburned when under 2 km altitude, and 45 minutes between the 2 km and 10 km range. This is supported by the data we received, which comes with a significant margin of error. Looking forward, there are aspects in which we excelled in with our payload, and other aspects that we can improve on to be able to obtain our own reliable data.

Our payload did exceptionally well in power, insulation, and protection. Our thorough testing helped significantly in these areas, and having a durable stuffed animal that could be altered as we needed made the construction process fairly straight simple. Establishing solid insulation and protection for our payload ensured that we could power our payload for the duration of the flight.

These highlights of our payload, however, were overshadowed by a small weakness that compromised our data collection system. The misconnection with the VEML 6075 undoubtedly caused our system to fail. Looking forward, to ensure our payload is robust for subsequent launches and to prevent any future malfunctions, we will construct our program to gather all possible data that is available to it, even if other portions of our system fail. It will also be beneficial to perform a hardware check prior to launch to ensure everything is set up properly.

DOCUMENTATION

Works Cited

GPS data graphed on Google Earth collected by SPACE 584 students

All other data collected by Seal Team 9 (Team 9)

Almanac Editors. (2019, April 18). Sun Safety: How Long Does It Take To Burn?. In *UV Index Scale*. Retrieved April 25, 2019, from https://www.almanac.com/content/uv-index-scale

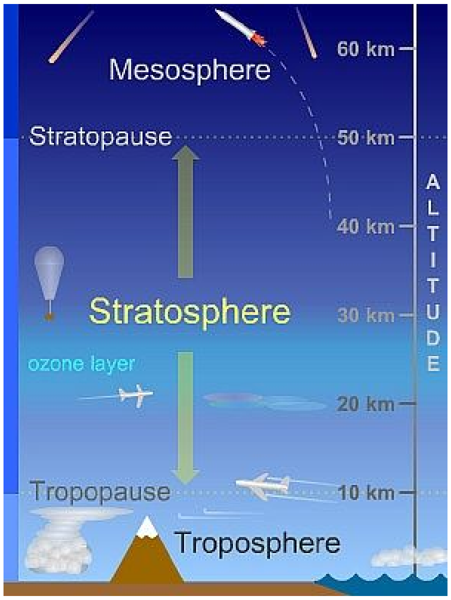
Russel, R. (2011). The Stratosphere - overview. In *University Corporation For Atmospheric Research*. Retrieved April 25, 2019, from https://scied.ucar.edu/shortcontent/stratosphere-overview

UVA and UVB Light Sensor with I2C Interface [PDF]. (2017, February 8). Vishay.

Wikipedia. (2019, April 13). List of U.S. states and territories by elevation. In *Wikipedia*. Retrieved April 25, 2019, from https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_elevation

Appendix A: Diagrams

A1: Outline of the atmosphere and what occurs in each region



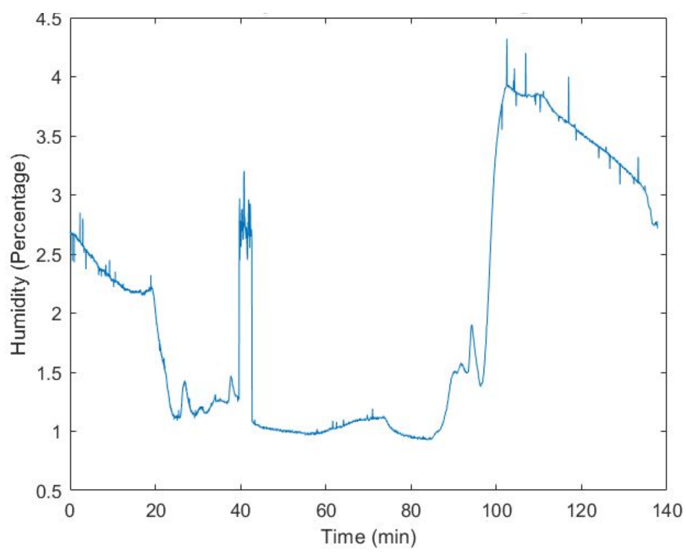
A2: The time to sunburn and methods for preventing sunburning at each UV Index number

UV Index Number	Exposure Level	Time to Burn	Actions to Take
0 1 2	Low	60 minutes	Apply SPF 30+ sunscreen; wear sunglasses on bright days
3 4 5	Moderate	45 minutes	Apply SPF 30+ sunscreen every 2 hours; wear a hat and sunglasses; seek shade during midday hours (10 a.m. to 4 p.m.), when the sun's rays are most intense
6 7	High	30 minutes	Apply SPF 30+ sunscreen every 2 hours; wear a wide-brimmed hat, sunglasses, and a long-sleeved shirt and pants if practical; seek shade during midday hours (10 a.m. to 4 p.m.), when the sun's rays are most intense
8 9 10	Very High	15-25 minutes	Apply SPF 30+ sunscreen every 2 hours; wear a wide-brimmed hat, sunglasses, and a long-sleeved shirt and pants if practical; seek shade during midday hours (10 a.m. to 4 p.m.), when the sun's rays are most intense; limit time outdoors
11 or higher	Extreme	10 minutes	Apply SPF 30+ sunscreen every 2 hours; wear a wide-brimmed hat, sunglasses, and a long-sleeved shirt and pants if practical; seek shade during midday hours (10 a.m. to 4 p.m.), when the sun's rays are most intense; limit time outdoors

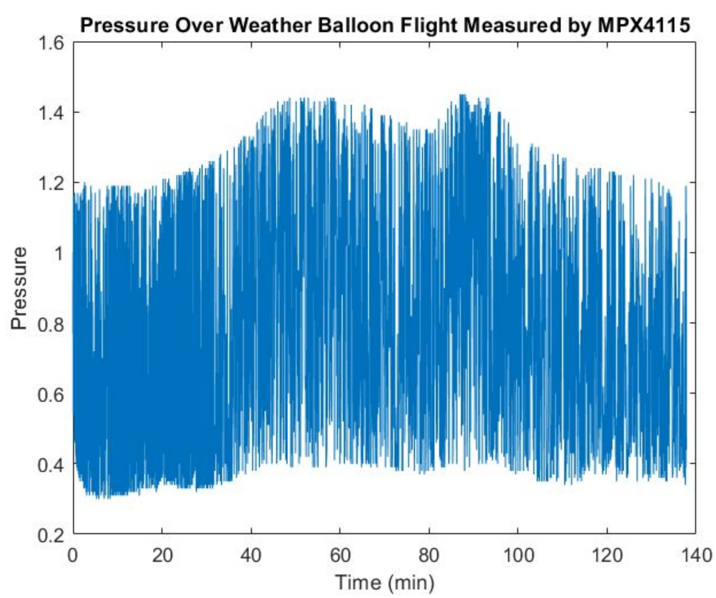
Appendix B: Data Graphs

All data from SEAL TEAM 9 because our payload failed to collect data during the launch.

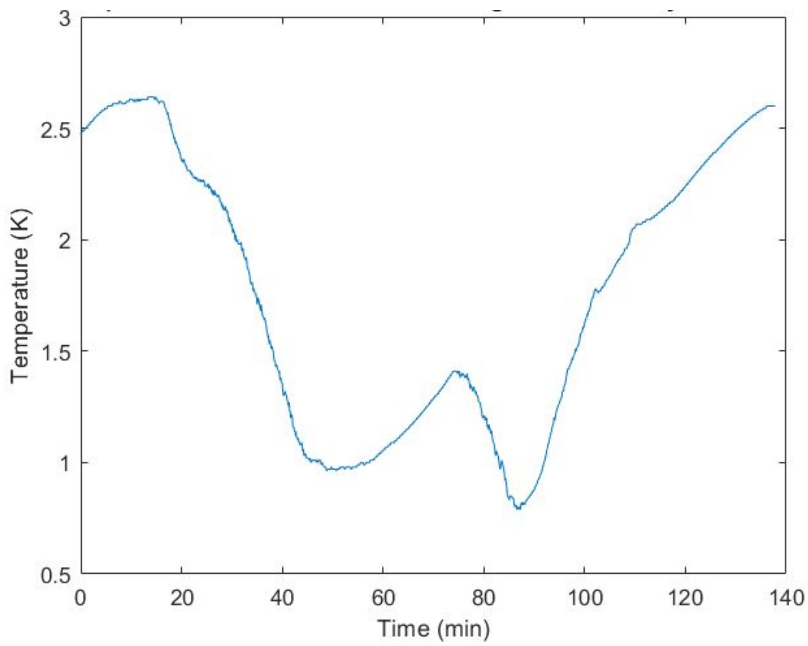
B1: Humidity measured by HIH-4030, likely inaccurate or miscalibrated as the recorded values were at most 4.5%, when the actual humidity was 60%



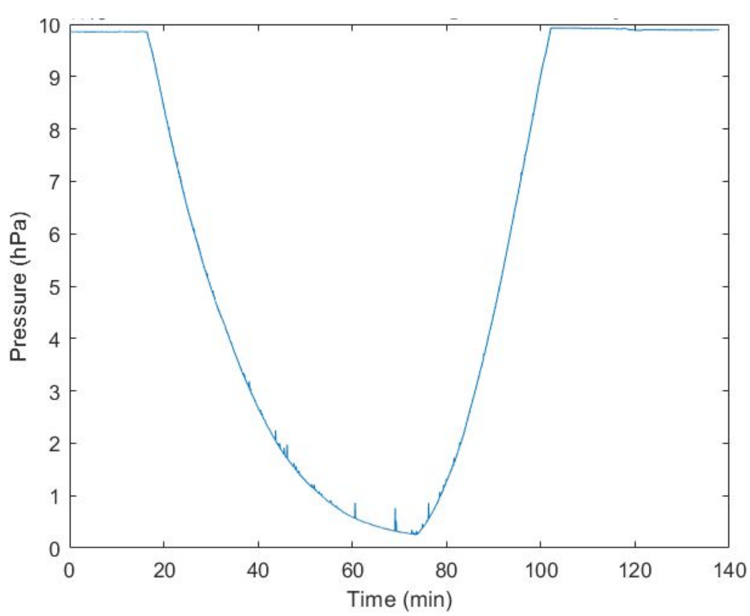
B2: Pressure measured by the MPX4115, likely malfunctioning with seemingly random and arbitrary measurements



B3: Temperature measured by a likely malfunctioning thermistor, reaching at most 2.75 K



B4: Pressure measured by BMP280 over the course of the flight (hPa * 10^4)



B5: Altitude measured by BMP280 over the course of the flight (meters * 10^4)