Background

To comprehend the basis of and the function of the weather balloon, attention must be diverted to components and terminology associated with such. Foremost is the environment into which the balloon is being sent, which invariably must affect the design of the aforesaid balloon. The target area to which the balloon is being sent is the atmosphere of the Earth, which is comprised of several individuals layers. Beginning from the closest shell to Earth, there is the Troposphere, Stratosphere, Mesosphere, Thermosphere, and the Exosphere. For the purposes of practicality, only the troposphere and the stratosphere will be discussed. The Troposphere is about 0-7 miles above sea level, and contains the majority of the weather, whilst the Stratosphere resides from the top of the Thermosphere to about thirty miles above sea level, absorbing the brunt of the harmful radiation exuded by the Sun, and has a temperature range of about 0 degrees Celsius. Thus, the materials that were implemented in the weather balloon's sensors were chosen accordingly. To insure both a safe landing in regards to living objects and the equipment upon decent, as well as doubling as insulation to negate the derogatory effects of cold upon electronics, a styrofoam carton was utilized as the housing of the equipment. Additionally, the styrofoam was easily turned to our purposes for cutting and fitting sensors in the payload. Within the styrofoam was a Raspberry Pi, GPS, auxiliary battery, Gopro, Pi camera, as aforementioned within the abstract. The Raspberry Pi was primarily to provide a platform from which we could obtain data from the onboard sensors and furnish an additional camera, which unfortunately did not function as planned, whilst the Gopro was to capture footage of both ascent and descent, with a disassociated GPS such that we could recover the balloon expediently without having to wait for an individual to both find the balloon and call the number inscribed on the payload, as well as note the wind patterns implied in balloon drift. Finally, the auxiliary battery granted power to the rest of the systems implemented in the balloon. As a weather balloon is called such, a meteorological balloon was attached to the payload to receive the helium and thereby provide sufficient lift to impel the balloon upwards.

Purpose

Our purpose in this project was to investigate near space conditions with various sensors and gather video footage of near space to get breathtaking photos and promote interest in science. Another purpose for our first flight was to have control data for our upcoming flights, where new systems will be implemented to achieve higher altitudes and durations. One possible method would be the inclusion of a pressure release valve to slowly release helium, which would prevent the balloon from popping keeping it up for a longer period of time.

Hypothesis

We believe that by releasing some of the helium in the stratosphere using a release valve, we can delay the balloon from bursting for several hours and allow us to stay in the stratosphere for a longer period of time, because the expanding balloon is prevented from reaching the point of bursting.

Safety:

Our group kept the weather balloon payload under 4 pounds according to FAA regulations and attached a radar reflector underneath the payload to alert possible aircraft. We also logged a call with the FAA in order to notify them of our launch. We launched the balloon from a flat, rural area with no obstructions and made sure that our project was marked with notices about the contents and purpose of the payload. It was recovered on Wednesday, February 27th, in a field undamaged.

Procedure

Our group has worked for months teaching ourselves and others in the group about different components of our payload to ensure we knew the most about what we were working with. We spent the first few months of work learning about other people's launches to ensure ours would be as well done as possible. First off, we estimated our flight time to be 3 hours and 55 minutes using a website with a flight calculator (habhub), the same one we used for our flight pattern, and ended up actually being in flight significantly less at 2 hours and 27 minutes. With this calculator, we also were able to estimate the burst altitude, which was estimated to be 99,000 feet. We also utilized our GoPro's videos to time when we started, when the balloon popped, and when it landed relative to when we started our computers. We believe that our time had been significantly shorter than the estimated time due to the parachute allowing it to fall much faster than anticipated. We built our payload (named "Major Tom" to pay homage to David Bowie) out of a styrofoam cooler because it is light, durable, insulated and disposable. A 10,000 milliamp-hour battery bank was placed in the very bottom of the cooler to increase stability and provide power for the duration of the flight. Our sensors and computers on board were powered by a Raspberry Pi minicomputer. The Pi was chosen for being cheap, extremely light, and power efficient, all characteristics that we found necessary to the balloon´s functionality. For logging data, a Raspberry Pi SenseHat was programmed to record temperature, pressure, humidity, acceleration, and magnetic data every 30 seconds, as well as pictures from the integrated Pi camera. These elements were selected for their compatibility with the Pi computer. Our capsule was fitted with a GoPro Hero to take 720p HD video because of its superior durability and quality for its weight. A four foot parachute designed for model rocketry was fitted to the cooler to make the descent as smooth as possible. Most importantly, our payload was equipped with a Spot Trace GPS Unit to track the balloon when it landed. Before launch, we ended up using an online tool to find the amount of helium needed to lift our payload, weighing 3.65 pounds, and added extra to give it enough positive lift to travel faster at a small cost of slightly lower altitude. The volume of helium needed was 60 cubic feet and we were able to calculate this at the time of the launch by measuring the diameter of the balloon periodically until it reached 4.85 feet. The GPS we chose was beneficial due to its compact design, easy online user interface, and a separate battery supply that could last for weeks in the event of a system power failure. System components were tested for low temperatures by being placed in a freezer while active, though the temperatures were not as cold as during the actual flight.. Unfortunately, our tests had not anticipated any interference with the Raspberry Pi putting out signals that interfered with our GPS unit, causing the payload to be Missing In Action for 3 days until we had blizzard conditions that caused the payload to move and start sending out signals again.

Images of Procedure

Programming the Raspberry Pi

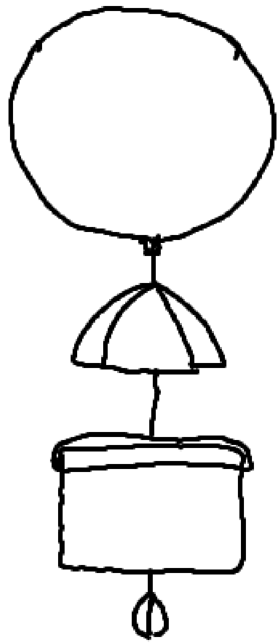
Finalizing the cooler and performing final system checks

Attaching the radar reflector

Inflating the balloon with helium

The launch crew

Directly after launch

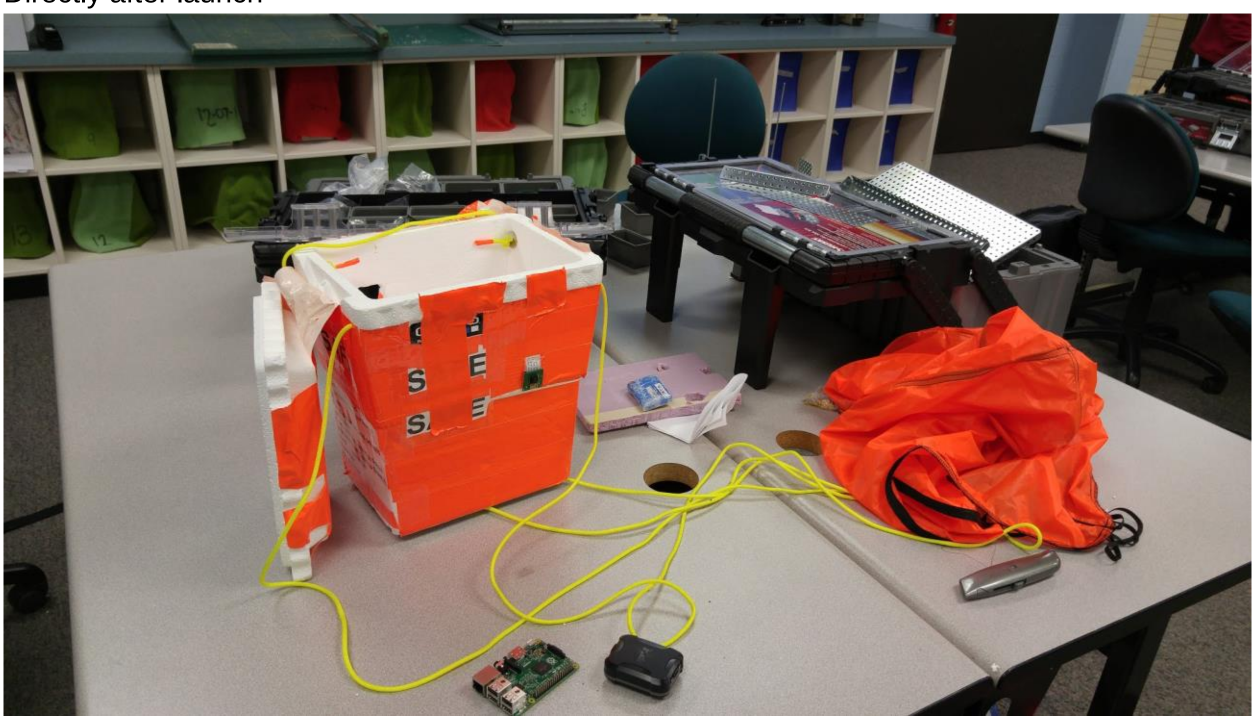


Balloon

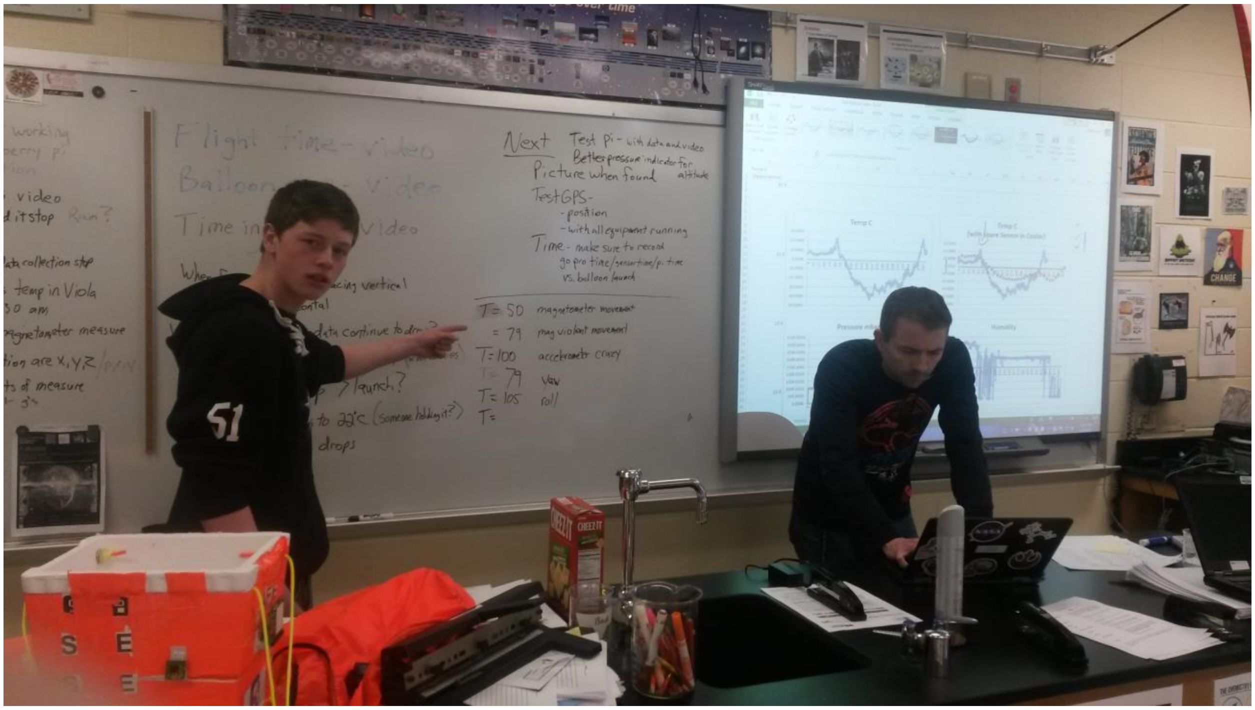
Parachute

Cooler with payload

Radar deflector

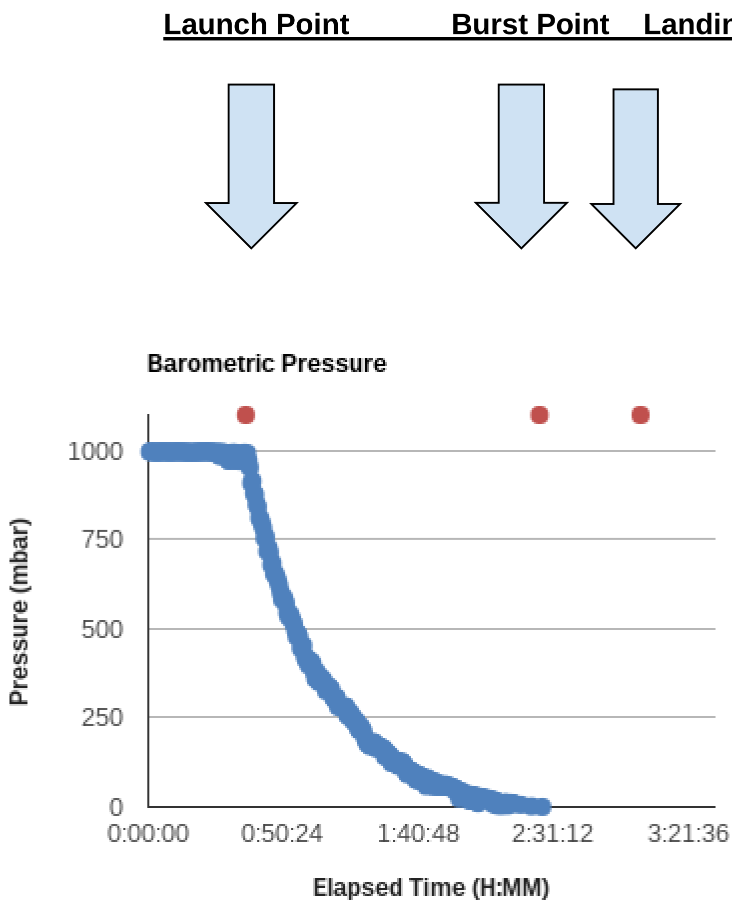


Unpacking after recovery



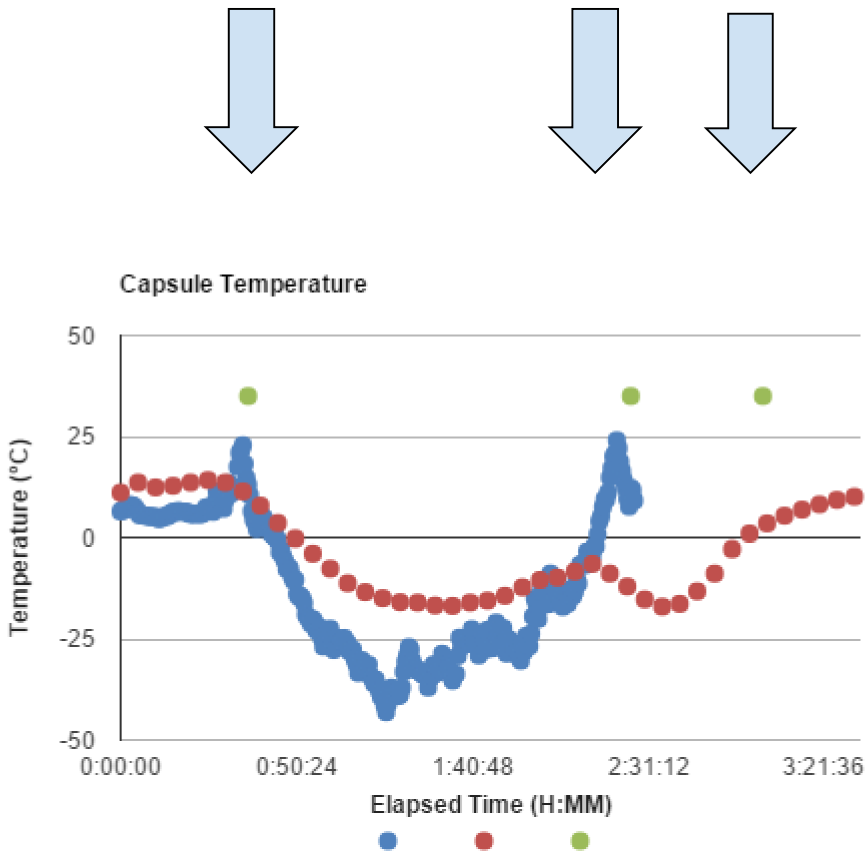
Analyzing data

RESULTS

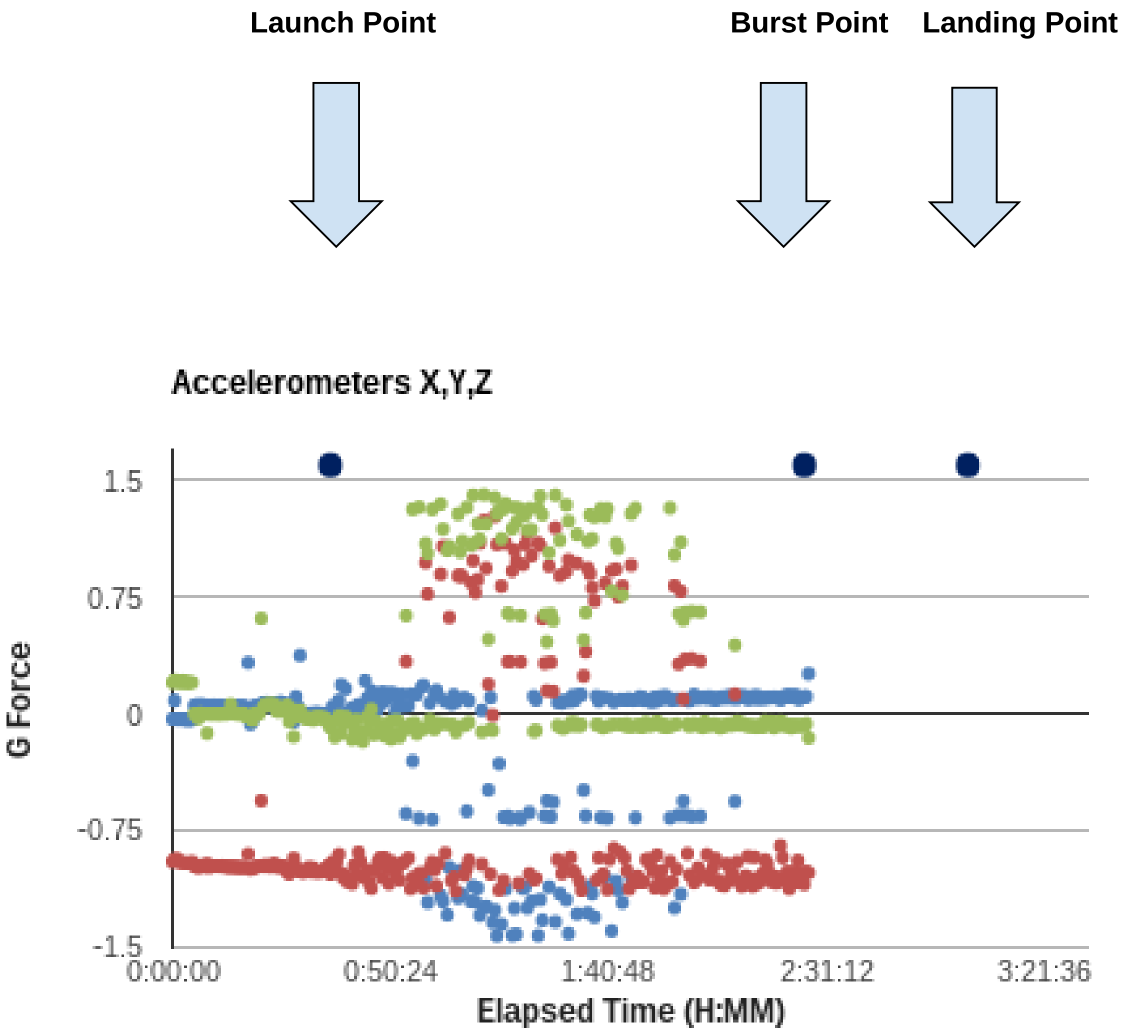


Despite the missing data, we can determine the pressure started to decrease and most likely would have followed a quadratic curve on its descent. The pressure unit that we used was the millibar. We can see as the balloon's altitude increased, the pressure decreased following an exponentially decaying model.

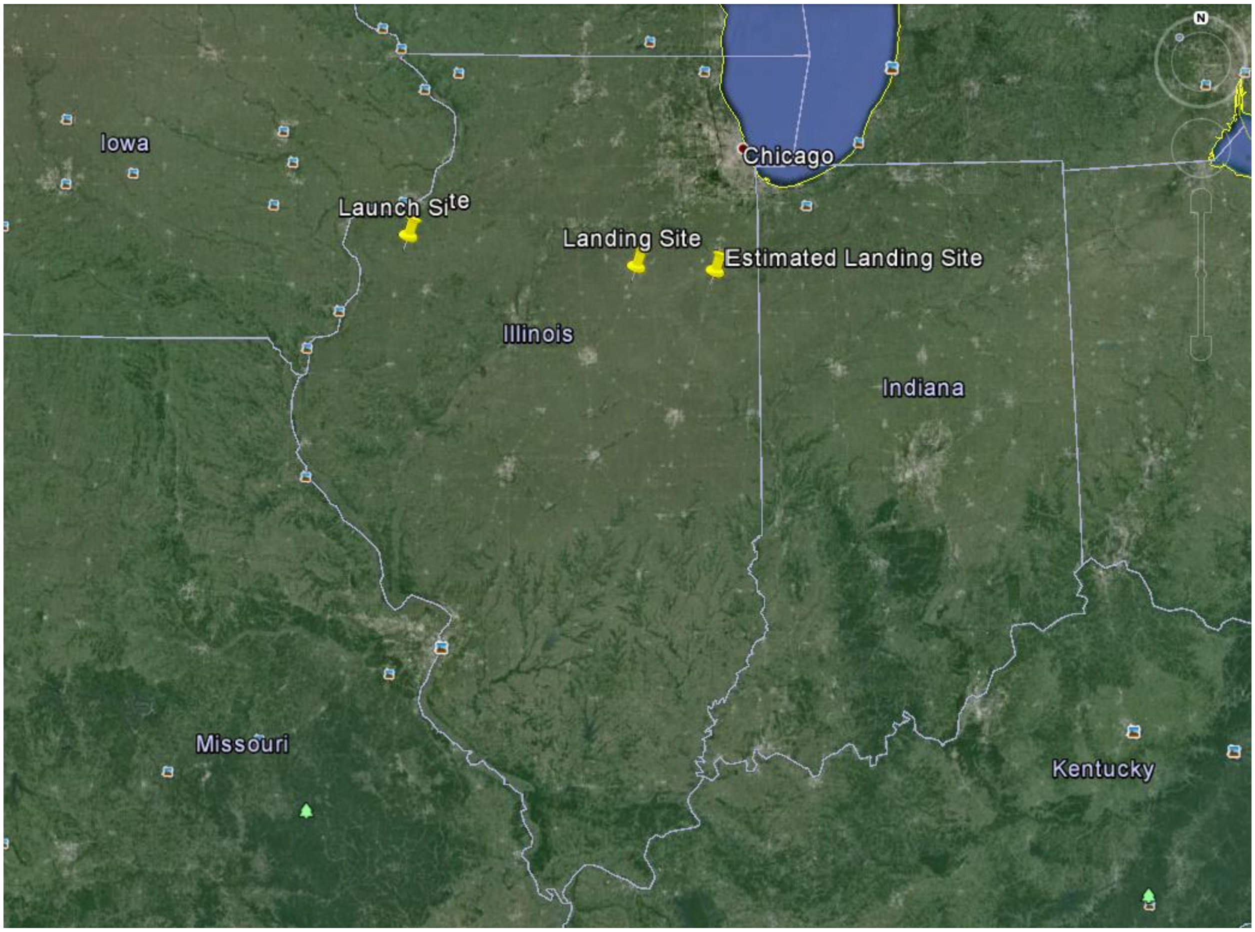
Launch Point Burst Point Landing Point



Our temperature data, represented by the above graph, yielded the most accurate data for our project. The blue line represents our thermometer on the outside of our capsule, explaining the lowest temperature drop of the flight. The red line represents a thermometer on the inside of our capsule, explaining why the temperature did not go down as far due to the insulating properties of the cooler. The first green dot represents the actual launch time of the balloon, with a temperature rise before the initial launch due to our body heat and working in close quarters preparing the launch. The second green dot represents the bursting point of the balloon. The pressure got to such a low point that the balloon, as seen in our videos, expanded and caused the balloon to burst. While some may think that the temperature would be at the lowest point here, this is not true due to the sun exposure rapidly heating in the near vacuum at the edge of space. The final green dot on the graph represents the landing, where the temperature inside the capsule starts to taper off due to less exposure and its descent to the Earth.



Above is the graph of the acceleration in the X,Y, and Z planes.



Flight path, predicted vs. actual.

Pictured above is our launch site, our estimated landing location, and our actual landing location. The final landing site was 20 miles away from the estimated landing site and the Balloon traveled 110 miles away from the original launch location.

Errors made

Our experiment did not go exactly as planned when we launched. Our biggest flaw was the GPS. We had not anticipated that our systems would interfere with each other the way that they did, which ended up almost causing a fatal test run that would have resulted in a loss of data and our breathtaking video footage. The temporary loss of GPS connection did not result in any data loss despite the hair pulling that occurred. We will be able to fix this in our next run by altering the GPS and Raspberry Pi's positioning in the new capsule design to avoid all interferences, as well as shrouding the Pi in a shield. Another mistake that we believe we had made in our first launch is the Raspberry Pi and SenseHat turning off and ending data recording after the pop. We believe that the Raspberry Pi and SenseHat were not fit for the extreme conditions of the upper stratosphere, such as the bitter cold (-43 Degrees Celsius) and very low pressure, causing it to shut down after its highest point in the flight, or it ran out of space because data was being stored on the ram instead of being stored onto the SD card.

Conclusions

Looking forward, we realize that our experiment is far from over and we have many more launches to come due to the success of our first experiment going viral online. Our video has accumulated over fifty one thousand views and has led to articles on several sites around the world including an interview done by TIME For Kids. We are currently working on making our next capsule, code named "STARMAN". The proposed design would include improvements such as the removal of the Raspberry Pi camera to reduce weight and improve performance with the Raspberry Pi, shielding on the Pi to prevent the interference we received on our first launch. We will also include a smaller battery bank, and larger storage capacity in the form of a 64 gigabyte SD card, which should fix the loss of sensor data. These fixes should allow for longer data gathering that will take us from launch to after landing, and hopefully will provide us with less errors as well. Other improvements include the addition of an altimeter to judge the distance and altitude of our flights more efficiently and the pressure release valve to extend the flight time. One main redesign of our project will be to make a larger and more durable capsule that will keep gps in a proper orientation, as well, allowing us to do more launches and not have to make new capsules with each launch.

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