Up, Up and Away: Two Balloons' Journeys to the Edge of Space

Cassandra Brown, Maura Cosman, Ambika Goel, and Carly Ingrao

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A Balloon's Journey to the Edge of Space

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Franklin W. Olin College of Engineering
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1 Objective

The goal of this experiment was to send a weather balloon into the Earth's amosphere, approximately 80,000 feet above sea-level. The balloon was to be sent up with a payload containing a circuit-arduino setup that measured and recorded atmospheric temperature and pressure, a digital camera to take timelapse photos, and a phone equipped with GPS capabilities for easy tracking. We were going to purchase all of the materials, design and build the circuit, hack the camera, set up the GPS, and perform preliminary tests for the purpose of this experiment, in the hopes of eventually retreiving real, interesting, and exciting data from the atmosphere on our final launch.

2 Procedures

The following will outline the execution of the experiment:

2.1 Preliminary Research

The beginning of this project involved a lot of research and careful planning. In order to legally send a weather balloon into the atmosphere, there were several FAA Regulations that we had to follow, the most important of which were:

- The payload had to remain under 4 pounds
- The balloon we launched had to land outside of restricted airspace (airports, military bases, etc.)
- The FAA had to be notified of our launch about 24 hours prior to lift-off

Knowing those guidelines, our next step was to plan out our actual system. The weather balloon would include many different components that would come together to fulfill our objectives. The system consisted of the actual balloon and rigging, the parachute, and the payload. The payload, by far the most complex part of the experiment, was a thick foam box filled with our data-gathering-and-recording circuit, our hacked timelapse camera, and our GPS phone. The complete itemized list is as follows:

- 8.9 foot, 200 gram weather balloon
- Parachute

- 50 feet of 500 pound nylon cord
- 1 inch O-ring
- Small D-clip
- Zip-ties
- Thick-walled styrofoam box
- A Canon PowerShot A530 camera
- Real Time Mini GMS/GPS/GPRS Car Tracker with T-Mobile Service
- Circuit with LM35DT (temperature) and NSCANN015PAUNV (absolute pressure) sensors
- Hand Warmers

Figure 1: Final Weather Balloon Supplies

2.2 Circuit Design

Our means to data collection was an Arduino Uno. This was connected to our circuit which contained two sensors–the LM35DT temperature sensor and the NSCANN015PAUNV absolute pressure sensor which would measure the temperature and pressure of the atmosphere as the balloon ascended. In order to determine the outside temperature and pressure, the sensors were wired through a small hole cut in the box and carefully taped to the external side of the payload. The final circuit is shown in the figure below. The pressure sensor was unamplified, so it had to be calibrated in Matlab.

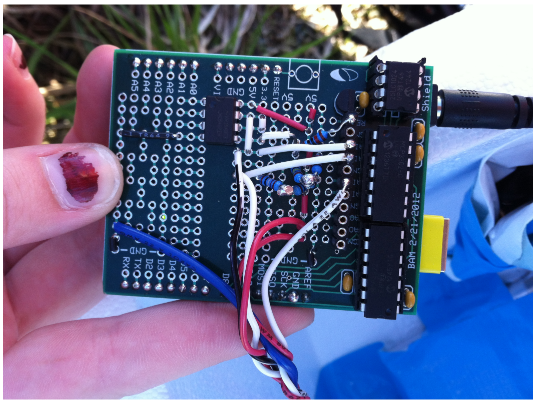

Figure 2: Final Weather Balloon Data Collection Circuit

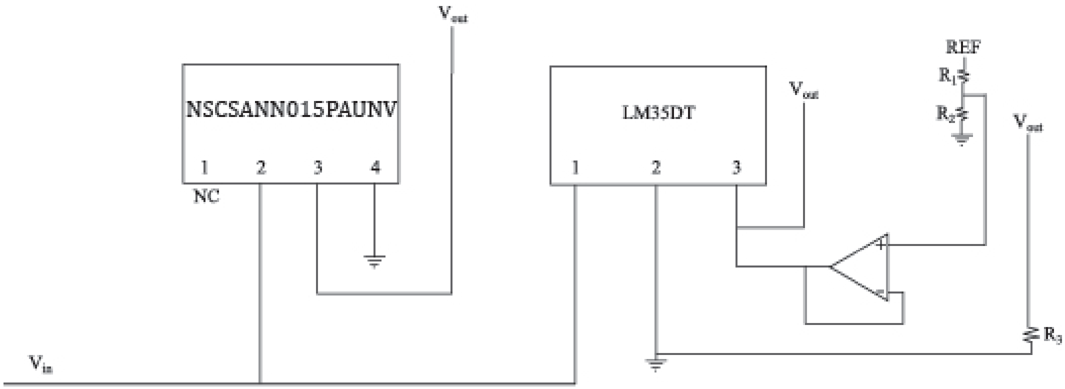

Figure 3: Final Weather Balloon Data Collection Circuit Schematic

2.3 GPS Tracking

In launching a weather balloon, often the most difficult part is retrieval. In order to make this as easy as possible, we launched the weather balloon with a portable GPS device. We used a T-Mobile SIM card and prepaid plan, which allowed us to cheaply send and receive GPS signals from the ground, helping us to track the whereabouts of the balloon. In order to receive a GPS location, a phone on the ground had to call the GPS device and the device would return a text with the GPS coordinates, which we would then input onto Google Maps.

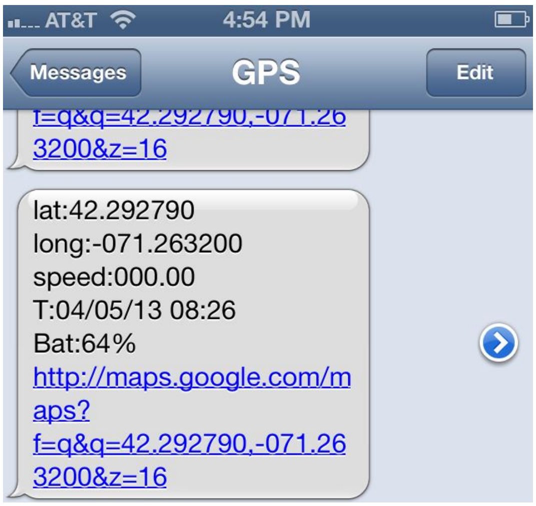

Figure 4: Received Coordinates from GPS Device

2.4 Hacked Camera for Timelapse Photos

In accordance with the advice we were offered by previous weather balloon teams, we purchased a Canon PowerShot A530 because PowerShots are easily hacked using scripts from http://chdk.wikia.com/wiki/CHDK. These scripts allowed us to program the camera to automatically take photos at any time interval. We chose to have pictures taken every 15 seconds until the SD card ran out of storage space or the camera battery died.

2.5 Payload Design

Our payload was a 9X12 single-piece styrofoam box with 1.5 inch walls. On the outside bottom of the payload, we glued large foam feet to absorb a little impact when the box fell in its descent. We cut two holes in the foam, one to wire our sensors through and a second larger one on the bottom for the camera lens. For the camera lens hole, we also epoxy-glued a clear piece of plastic to form a window to both protect the camera from impact and to seal the box from the cold. Inside the box, we taped down the camera, circuit, and GPS device to prevent shifting when the box was falling. We tried to keep the weight distribution pretty even

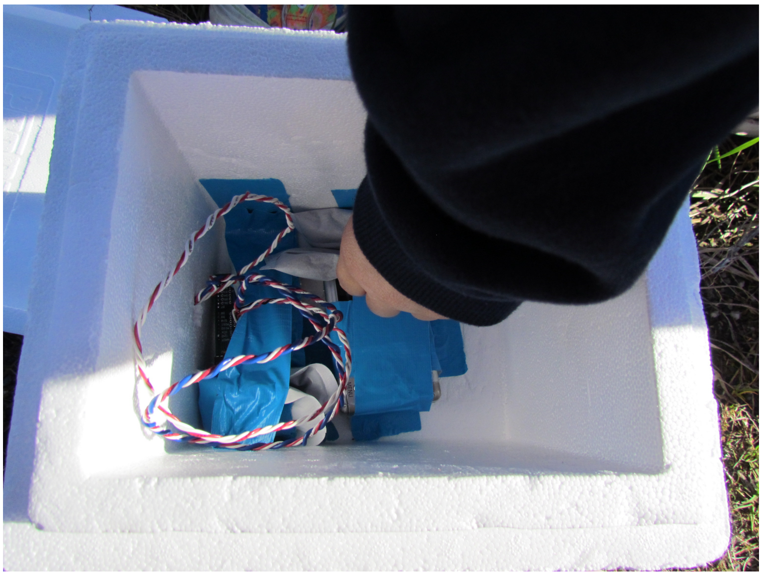

Figure 5: The contents and final set-up of the payload

throughout the payload and then filled the box with hand-warmers to keep the batteries from malfunctioning in the cold. We tied the nylon cord around the box, through a self-cut hole in the parachute and onto the D-clip attached to the balloon opening. We then duct taped the nylon cord down to make sure it wouldn't slip.

2.6 Preliminary Circuit Testing

Obviously the purpose of the weather balloon was to retrieve interesting data pertaining to Earth's atmospheric conditions. Because this was so crucial, we decided to extensively test our electrical system prior to our official test launch, even in negative temperatures. After putting the whole system in the freezer for about 15 minutes, we had the below pressure and temperature data, assuring is that our circuit was functional.

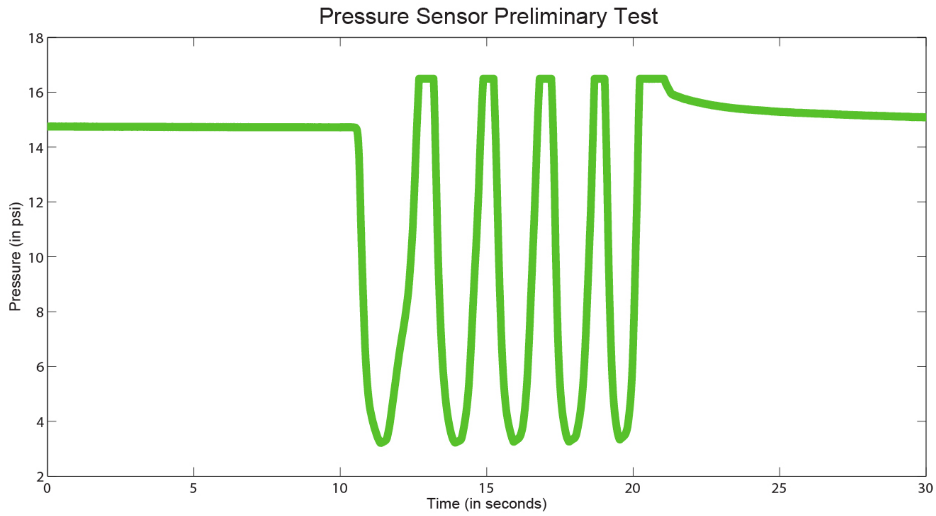

Figure 6: The above shows the pressure change while the sensor was attached to a syringe and the plunger was stressed and relaxed.

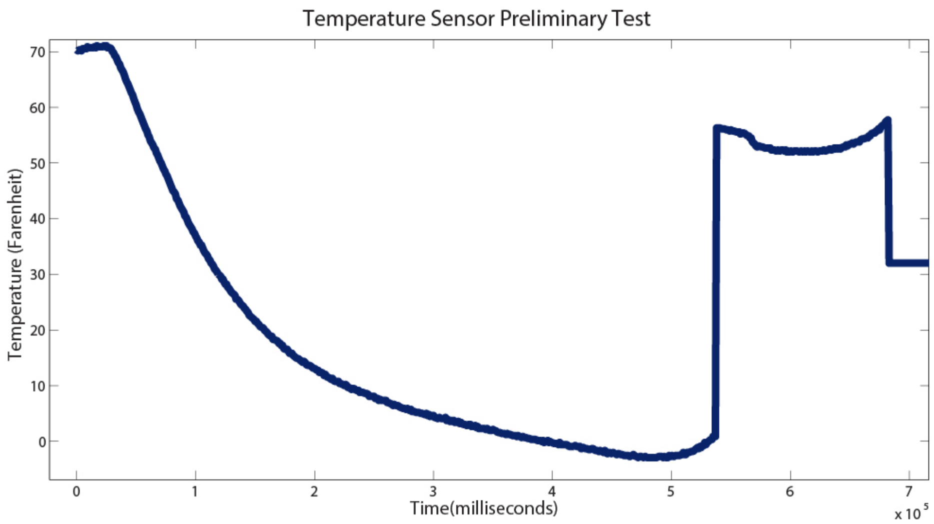

Figure 7: The above shows the temperature change while the electrical system was placed in the freezer, taken out, and then placed in the fridge.

2.7 The "Tethered Launch Incident"

After everything (except GPS tracking) was finished, we decided to do a test launch to see if we could get some cute timelapse photos of Olin and to make sure we understood the procedures of a real launch. We planned on tethering our balloon and payload with 30 lb. fisshing line, and, except for turning on the GPS tracker, readied the package as if we were really going to launch. We donned our latex gloves, plugged in our circuit, programmed our camera, tied everything together, double checked our knots, duct taped everything down, and filled her up. Three of us made sure the balloon didn't touch the ground as the last monitored the helium tank. Finally when the balloon was more than able to support its own weight and was about 5.5 ft in diameter, we tied off the balloon opening with zip-ties, and gently let the line out. Then, tragedy struck. The line failed and all of our hard work flew away and we had no way of tracking it.

Figure 8: A failing in the tether caused our balloon to fly away

2.8 We Will Rebuild

Our official launch date up until the "Tethered Launch Incident" had been Saturday, April 27. As a result of this mishap, we pushed our launch day back to Saturday, May 4 in order to give us a little time to order new parts and rebuild the electrical system. Because we only had a week and a half to do what was previously three weeks of work, we ordered everything immediately and got to work on building the circuit. Everything happened at warp speed.

2.9 Launch Day v.2.0

The morning before the launch, we checked the predicted flight path of our balloon using CUSF's Landing Predictor. We launched out of an open field near Williamstown, MA and the balloon was predicted to land about 70 miles southwest in Spencertown, NY. The data from the predictor had been updated in the past hour. As you will see in our superimposition of the prediction and the actual GPS path, the prediction was remarkably accurate.

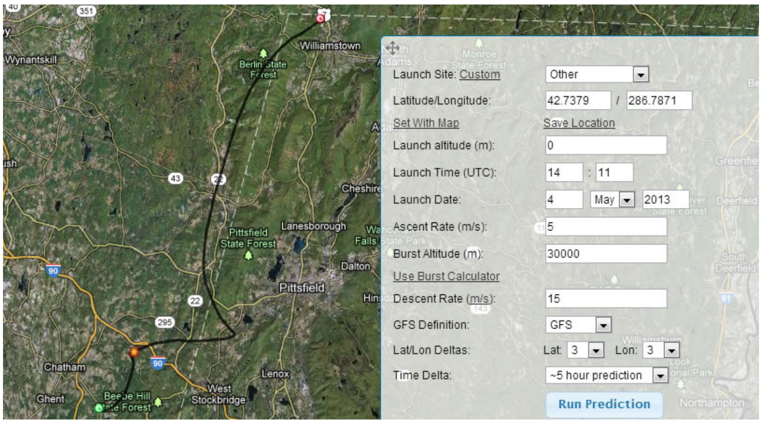

Figure 9: The predicted flight path of our weather balloon according to the CUSF Landing Predictor

We drove to the field, programmed the camera, plugged in the Arduino and circuit, replaced the battery in the GPS system, and taped everything down. After sealing the box with epoxy and duct tape, we wrapped the box in our nylon cord, ran the cord through the hole in the parachute, and tied it to the D-clip. We then began to fill the balloon with helium, sealed the mouth with zip-ties, and then double-wrapped the sealed mouth around the O-ring, fastening the mouth onto the washer with zip-ties. To receive GPS pings, we had to call the device with one of our cell phones. The balloon left cell range at about 6,000 feet, at which point we lost the balloon. It reentered range and we were again able to receive GPS signals.

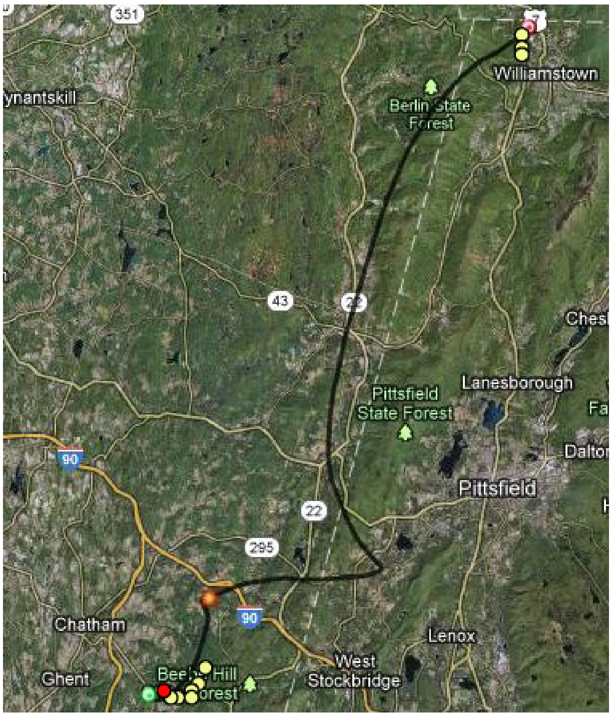

Figure 10: The predicted flight path of our weather balloon and a superimposed real flight path

After the balloon landed, we input the latitude and longitude coordinates provided by the GPS tracker and drove about an hour southwest to Spencertown, NY. We found the field that the GPS indicated the balloon landed in and combed the area for the balloon. We were unsuccessful in finding the payload in the first field, and decided to search several others. Much of the surrounding areas were forest, so we remained unsuccessful and left Spencertown when hunters began to fire guns in the near vicinity.

Figure 11: Double checking the payload

3 Results and Reflection

3.1 Results

Our original objective was to send a weather balloon into the atmosphere and to (theoretically) retrieve interesting data from our sensors and cool timelapse photos from our hacked camera. In the end, we believe we lost the balloon in a heavily-wooded area and were unable to retreive any data at all. In our preparation process, we were able to confirm that each component worked and gained data from artificially-created situations, but gained no real data from the atmosphere.

3.2 Reflection and Future Work

The most obvious problem with the project was retreival. We couldn't find our payload after its descent. This could have happened for several reasons, the most likely of which is that the balloon's landing location was in a densely-wooded area. A way to fix this particular problem would be to plan the launch so that the balloon would land in a flatter location.

On a higher level, this project was a really amazing opportunity to learn a lot. The scope of the project was incredibly wide and incorporated electrical, mechanical, and design engineering aspects, as well as a broad range of logistical issues to consider. It really allowed the entire team to travel out of our comfort zones (none of us are ECE's), especially in the circuit design and planning. Designing a circuit from scratch was different from anything we'd really done in Real World Measurements and it was helpful to learn how to utilize all of the resources available for this. Additionally, the logistical aspects of this project required us to learn how to take a lot of initiative and develop more thorough research skills.

Although we weren't "successful," our team gained a lot and learned so much about the planning and execution of a weather balloon launch. It was through our numerous failures (and few successes) that we were able to learn the importance of meticulous circuit design, sound mechanical design, and careful planning.

4 UPDATE

As of May 7, 2013 our tethered launch balloon was found on Revere Beach in MA. He left it in a place where other people (and potentially we) could find it. We went to go look for it and did not see it. On May 10, 2013 another person found the payload and called. We have yet to talk to him about how and when we should pick up the payload.