University of Minnesota and MN Space Grant Consortium

AEM 1905 Freshman Seminar: Fall 2010
Spaceflight with Ballooning
Team Project Documentation

Four Guys 1 Box

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Revision B

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0.0 Team Assignments --- See Appendix A

1.0 Introduction

Reaching outer space is a hard task, especially when you're not part of an organization like NASA. But reaching near space and seeing what goes on above the atmosphere, now that's possible. Our team is called Four Guys, 1 Box. The people that are involved in this team are Taylor Garcia, Brad Finley, Jason Checky and Salman Khan. We are planning on building a payload made out of Styrofoam that will contain a flight computer, weather station, a zigbee radio, two accelerometers, a heater circuit, and a HOBO that will be our data logger. This box will be launched into near space and will be attached to a balloon that will have other payloads on them as well.

Near space is important. Near space helps show some of the things that go on in and around the outer atmosphere. The physical qualities of the outer atmosphere are much like the qualities of outer space. This is valuable for experimentation. In near space you can test things like what might the Earths radius be and how a liquid object reacts when it's in that kind of atmospheric condition. We can also figure out a free fall time of an object also. This is important because understanding how items and things react in near space helps us figure out what happens in outer space.

Going into near space is a lot cheaper than going into outer space. Less money is involved and there's more that we can accomplish. By doing this experiment we are drastically reducing the budget to $840 compared to the millions it cost to go into outer space. It also is a lot easier to accomplish a near space task vs. an outer space task. We would need a lot more things to go outer space. We would need to pass through yards of red tape. We would need more testing and better materials, also more money.

Because near space travel is cheaper than outer space travel, it is more accessible to everyone. Near space programs can inspire young and old minds to take an interest in the cosmos. The near space programs of today can create the space programs of tomorrow. Today there may be a boy or girl out there working on their near space project, and tomorrow they will be helping to create the next form of space travel. Colloquial

2.0 Mission Overview

Our payload has been designed based on what we need it to do. Our payload box as a whole must meet several important requirements. The payload also has several tasks it must be able to perform during and after launch that are accomplished by the components within the box. Together meeting these capability requirements of the payload outline what needs to be done to ensure a successful launch.

The box itself must be able to withstand cold temperatures. We have addressed this issue by making our box out of Styrofoam and sealing any crack to give it insulation against the cold. The payload must also be resistant to violent shaking. To account for this we constructed the box out of strong one inch Styrofoam and fitted the sides together using a dove-tail method and we will use tape to give it additional strength. This will insure a sturdy box.

The components of the payload each have their tasks. All of these components and a few others which assist in the mentioned tasks will also all need to function together and function as expected for our experimentation to prove successful.

The weather station and the HOBO will serve the purpose of gathering weather-related data. This data will be used to find patterns between in the data, for example, relating temperature to altitude and/or pressure.

The heater will run on batteries and will be necessary to keep the batteries of each of the components warm enough to be functional. The Styrofoam construction makes this heating more effective.

Two accelerometers will measure the vibrations and the acceleration of the ascent and descent of the payload. A control accelerometer will be firmly attached to the inside wall of the box. The other accelerometer will be experimental and will not be firmly attached. This will be our other experiment and it attempt to determine difference in the acceleration put on an object within the payload when it is firmly attached or held within the box in a different way.

The still camera will be placed in our payload to capture periodic photos of the payload's journey. We will use the photos captured to do another experiment which will relate layer of the atmosphere and altitude to the appearance of the photos. We believe that we will be able to tell different layers of the atmosphere by their qualitative data.

3.0 Payload Design

There are limitations that are placed on every project that is undertaken. One such limitation is that the payload box has a finite interior area in which we will place our components. The interior is limited to a 6X6X6 volume, and the entire payload is limited to having a mass less than one kilogram. There are other requirements that are more general/practical requirements. One of these requirements is that the payload box must be structurally strong enough to withstand the forces on it during ascent and decent. Another is that, the interior of the box must maintain a high enough temperature for the chemical reaction inside the batteries to take place. When designing the payload and deciding the placement of parts inside the payload box, the limitations need to be kept in mind. If you forget or ignore a limitation it can force a rewrite of your design and start over the construction.

In designing our payload, we focused most intensely on the weight limitation. We wanted to cut the weight of the payload in any manner. By cutting unneeded weight, we left more weight for our experiments and a cushion for unforeseen weight problems. In designing our payload, we used a method of joining the sides of the cube together called doving. The purpose of the doving was to reduce weight by reducing the amount of adhesive material needed to hold the box together. Instead of adhesive, the doving uses geometry and shapes to keep the craft together. The use of doving raised some issues in the design and creation of the box. Most notable of these was that the bottom and top of the box had nothing to stop them from popping out, besides the static friction. This problem was overcome by using a single piece of strapping tape to circle the top and bottom of the box.

Parts

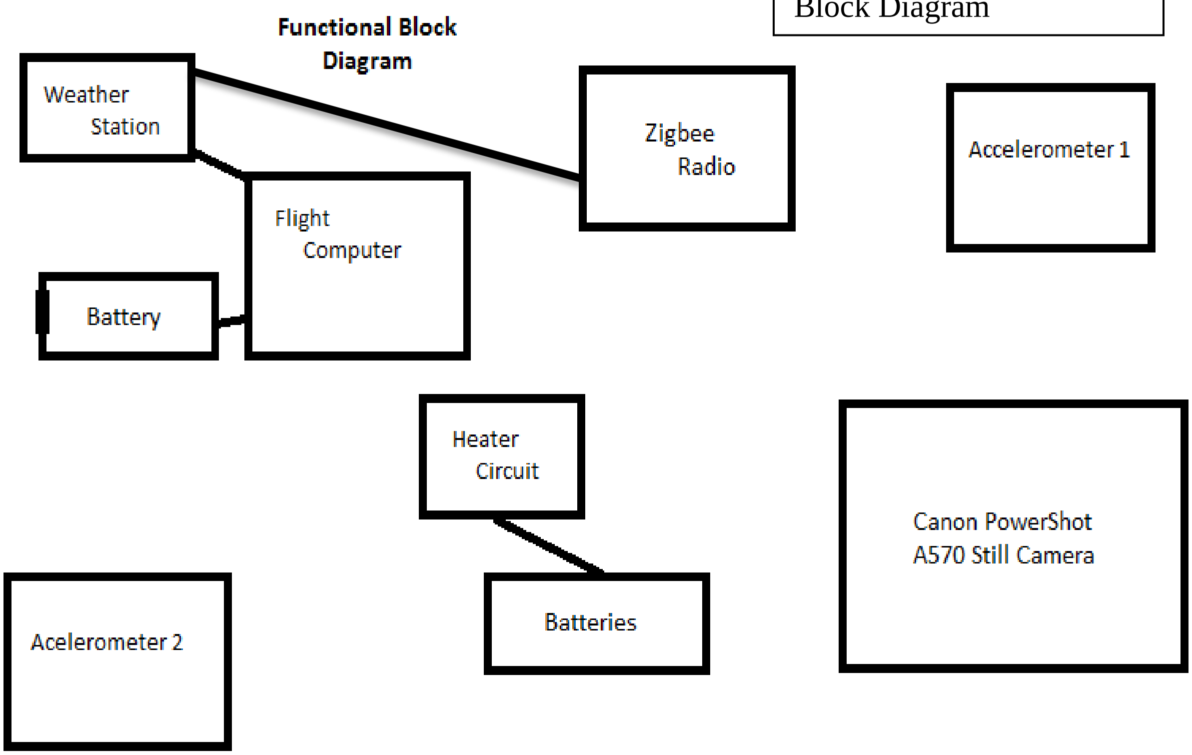
Building Materials

1. 1 inch Pink Styrofoam (6 panels 8X8inch)
2. String, Straws, and Key Rings (harness)
3. Epoxy (for sealing holes/cracks)
4. Zip Ties & Velcro (temporary)

Interior Hardware

1. Heater Circuit (with a 3 nine volt battery pack)
2. 2 Accelerometers
3. Zigbee Radio
4. Flight Computer (with 1 nine volt battery), and Weather Station
5. Hobo Data Logger (with temperature probe)
6. Canon PowerShot A570 Still Camera

Figure 3.1 – Functional Block Diagram



The only systems directly connected to each other are the weather station, zigbee radio which relays information from the weather station, flight computer, with its battery and the heater circuit with its batteries pack. In the case of the flight computer system, the flight computer is the center of the system. The batteries serve to supply the computer with power and the weather station serves to gather and relay data to the computer. In the heater circuit system, the batteries serve to provide power for the heater to produce heat. This heat indirectly affects all of the systems. The radiant heat serves to keep all the parts in their functional temperature range.

When deciding where to place the parts inside of the payload box, the temperature sensitivity of the part was considered. Objects with higher temperature sensitivity were placed closer to the heater circuit. We do not expect high temperatures during ascent and descent so the maximum functional temperature is not considered. Effort was made to make sure that the objects did not drop below their minimum functional temperature. With this in mind, we plan to place the batteries as close to the heater circuit as possible.

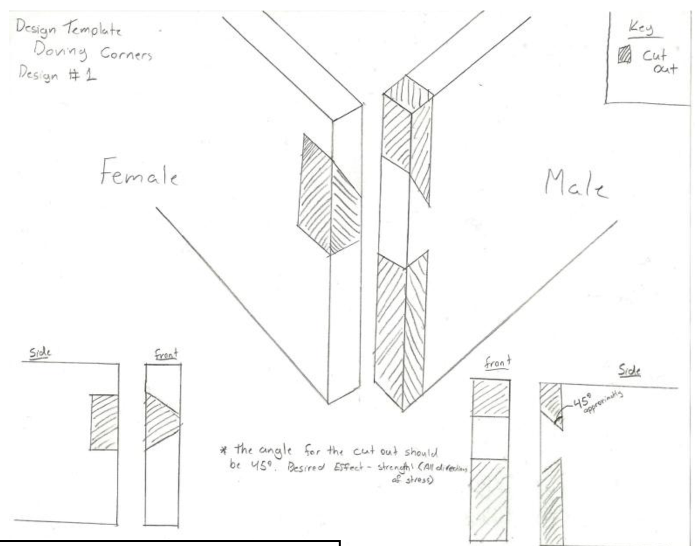


Figure 3.2 – Design of doving & corner attachment

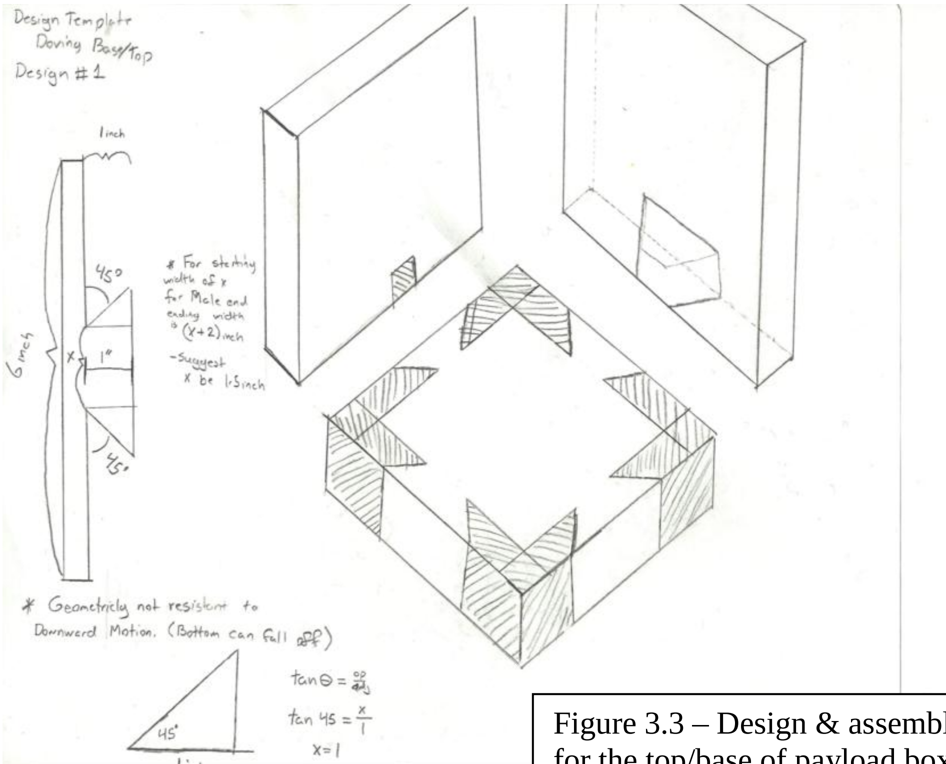
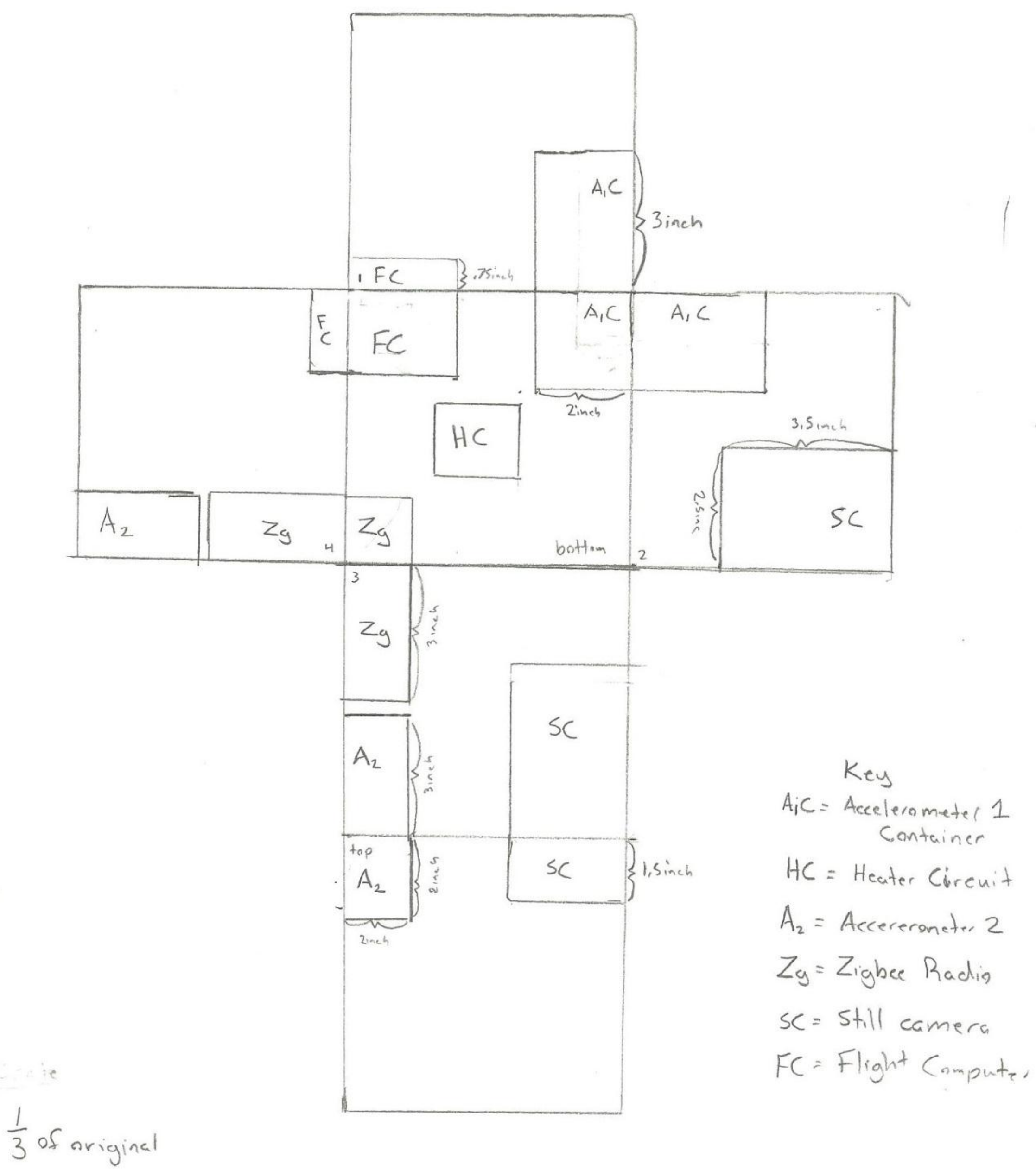
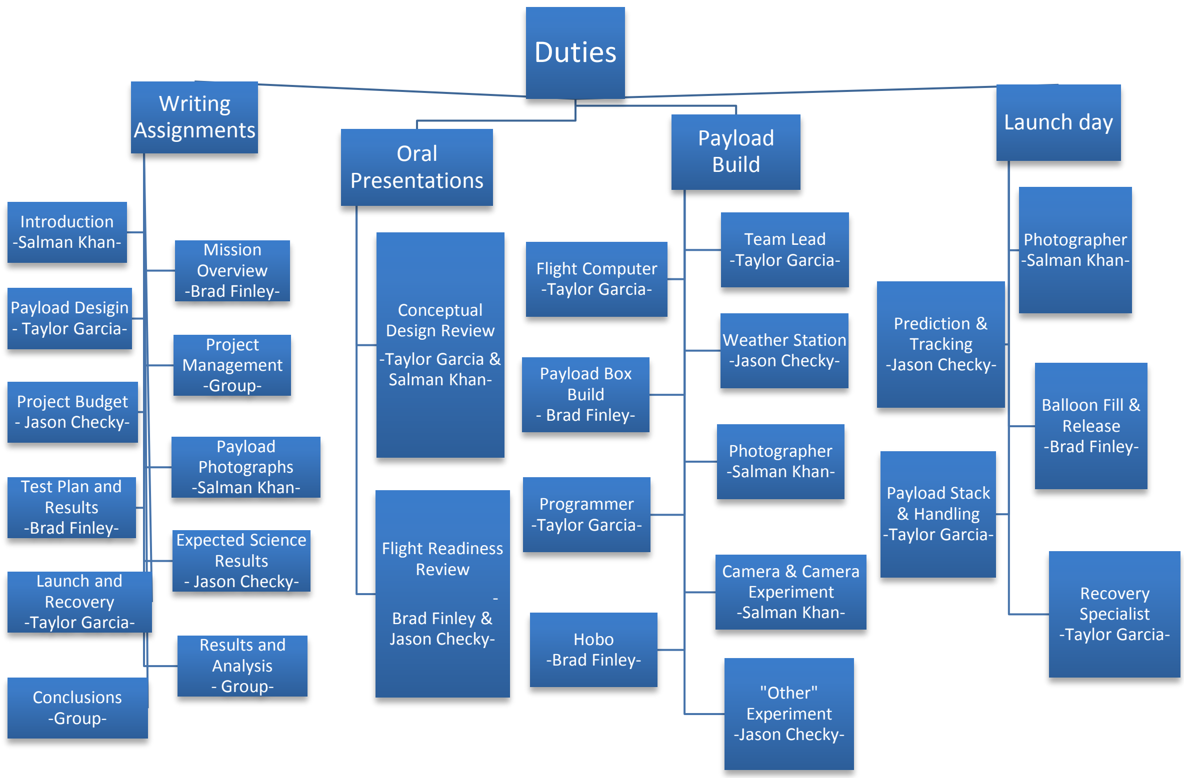


Figure 3.3 – Design & assembly for the top/base of payload box

Figure 3.4 – Payload part layout.



4.0 Project Management



Schedule

Sept. 20-27	Sept.28 – Oct. 4
Discussion on possible • Payload designs, • Camera experiments • Other experiments	Assigned responsibilities for Writing, project, team roles, and Launch day.
Team building activity: Rover Building	Discussion of possible experiments

Practice soldering

Oct. 5-11	Oct. 12-18	Oct. 19-25	Oct. 26-Nov. 1	Nov. 2-15
Work on revision A Discussed camera & other experiment.	Revision A Due Friday, Oct 15th by 4:00 P.M. Decided on camera and other experiment	Work on revision B Temperature test payload body and parts	Work on Revision B	Revision B Due Friday, Nov 5th by 4:00 P.M.
Payload body construction	Finished the building of the payload body	Team works on /finishes Assignments	Finish prediction work the 26th	Work on revision C
Team built flight computer and weather station.	Integration + Testing	Have parts zip tied in & know their final location on the box.	Weigh-in due the 28th	Data analysis work
Work on revision A	Work on FRR's	Present FRR's	Launch the 30th	Data analysis visuals
Get approval				

** There is one full team meeting scheduled every week on Thursdays meeting place is Northrop Plaza Mall**

5.0 Project Budgets

In order to make the flight to near space a reality, our team must work within certain parameters. These parameters include limitations on the cost of the payload box, the payload mass, and the time it takes to build it. Time is allotted and can be tracked using the group schedule under section 4.0. This section will address how money and mass is to be allotted to different parts of the payload design. To begin, we are limited to a mass of 1 kg of the completed payload box, including all exterior devices such as rigging. This constraint was set by the instructor and (indirectly) by the FAA. Under FAA guidelines, flown crafts exceeding a certain mass must be approved by the FAA before launch. Because we do not want to risk being denied launch approval on October 30th, we will avoid exceeding this limit. Additionally, each of the four groups in the course will be flying a payload. In the interest of fairness, all of the groups must comply with the same weight limitations. Thus, the payload must not exceed 1 kg in mass.

Money is not intended to be a limiting factor in this course. Instead, it is meant to be more of a reminder of the cost of the materials involved. As Figure 5.1 indicates, the total cost of the payload exceeds $800. Thus, it is important that the group handles these materials with care throughout the experiment. Although our budget is not officially and strictly capped, there are some experiments that are just not feasible with our available resources. For example, we would not be able to fly piece of equipment costing fifty thousand dollars; it would just not be possible.

The goal of the near-space project is to conduct experiments in an environment like that of space with a greatly reduced cost in time and money. So, staying within a reasonable budget best reflects the goal of this course.

The following figure shows each part of the payload box along with its mass and cost in money. These are totaled below at $881 and .966 kg. Thus, we are within a reasonable cost, as many of the materials are on hand in the classroom already. Additionally, we are tentatively under budget in mass if we assume the masses are exact and do not change before launch day. According to these results, we have a mass “cushion” of .034 kg to work with. (Note that the foam budget is for that of a 6X6X6 box. Some of this foam will be used in the construction of the additional accelerometer experiment).

1"-thick Pink Styrofoam	$8.00	0.150
Tubing, rigging strings, key rings, zip ties, glue, tape, mylar or paint, etc. (allowance)	$5.00	0.050
Heater circuit (battery pack listed separately) (required)	$5.00	0.027
3-pack 9-volt battery for heater (required)	$6.00	0.150
Weather station (will attach to outside of box) (required)	$40.00	0.015
BalloonSat Easy flight computer (required)	$30.00	0.033
9-volt battery for flight computer (required)	$2.00	0.046
Canon Powershot A570 IS still camera (choose between this and a video camera)	$166.00	0.223
HOBO data logger for interior "health" (may plug in up to 2 other sensors to HOBO) (required)	$130.00	0.048
HOBO temperature probe for additional temperature measurements	$29.00	0.010
Small solar panel (might use several, on different sides of box) (optional)	$8.00	0.008

Zigbee radio to send voltage data to the ground during flight (required)	$300.00	0.126
2x Accelerometer (optional)	$150.00	0.034
Totals:	$881.00	.966 kg

Table 5.1: this table shows the cost and mass of each part used in the payload box. These numbers are predictions and may not match the true values.

As noted previously, Figure 5.1 does not show the actual mass of each component. These are listed in Figure 5.2 as massed following launch:

Object	Mass (kg)
1"-thick Pink Styrofoam (enough for 6" x 6" x 6" box) (required, or else select foam-core) AND Tubing, rigging strings, key rings, zip ties, glue, tape, mylar or paint, etc.	.209
Heater circuit (battery pack listed separately) (required)	.025
3-pack 9-volt battery for heater (required)	.150
Weather station (will attach to outside of box) (required)	.015
BalloonSat Easy flight computer (required)	.030
9-volt battery for flight computer (required)	.045
Canon Powershot A570 IS still camera (choose between this and a video camera)	.2050
HOBO data logger for interior "health" (may plug in up to 2 other sensors to HOBO) (required)	.045
HOBO temperature probe for additional temperature measurements	.0095
Zigbee radio to send voltage data to the ground during flight (required)	0.1250
2x Accelerometer (optional)	.035
9-volt battery for zigbee interface board (required)	.045
Total:	.9385

Table 5.2: This table shows the actual masses of the payload components as measured following launch. Note that the payload box and rigging/adhesive components have been combined in the table.

6.0 Payload Photographs

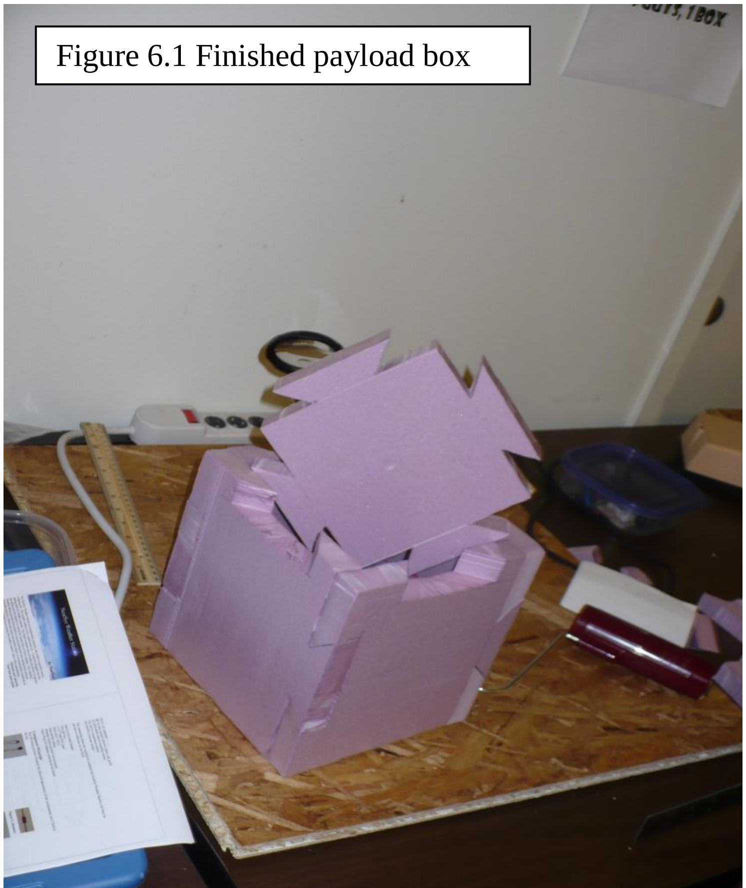


Figure 6.1 Finished payload box

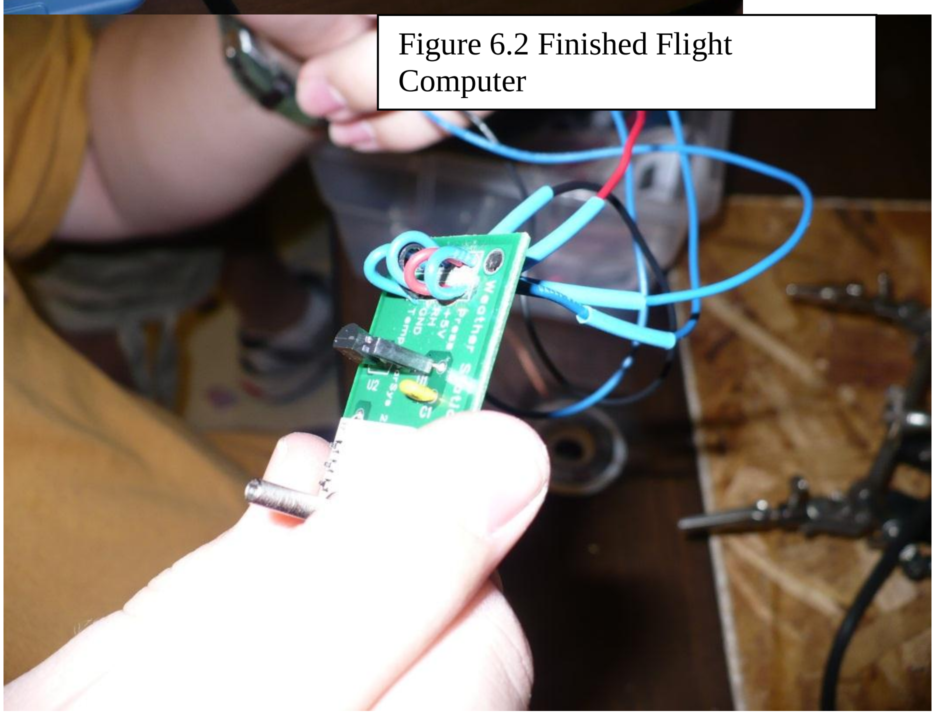


Figure 6.2 Finished Flight Computer

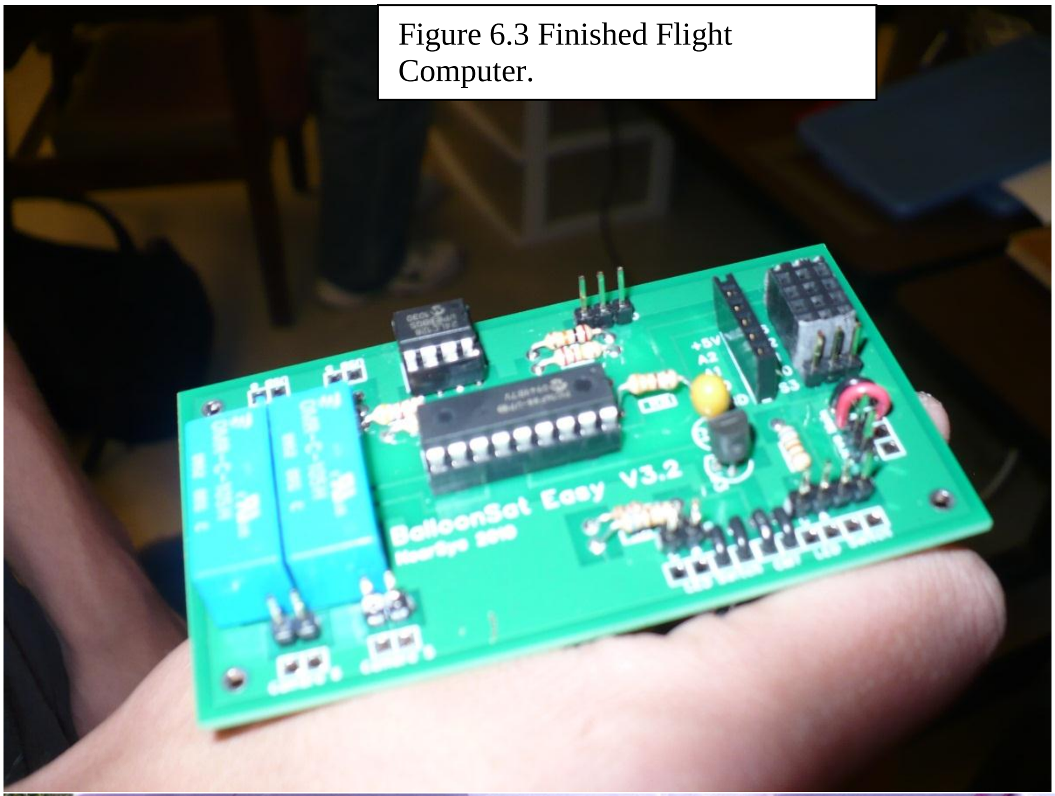


Figure 6.3 Finished Flight Computer.

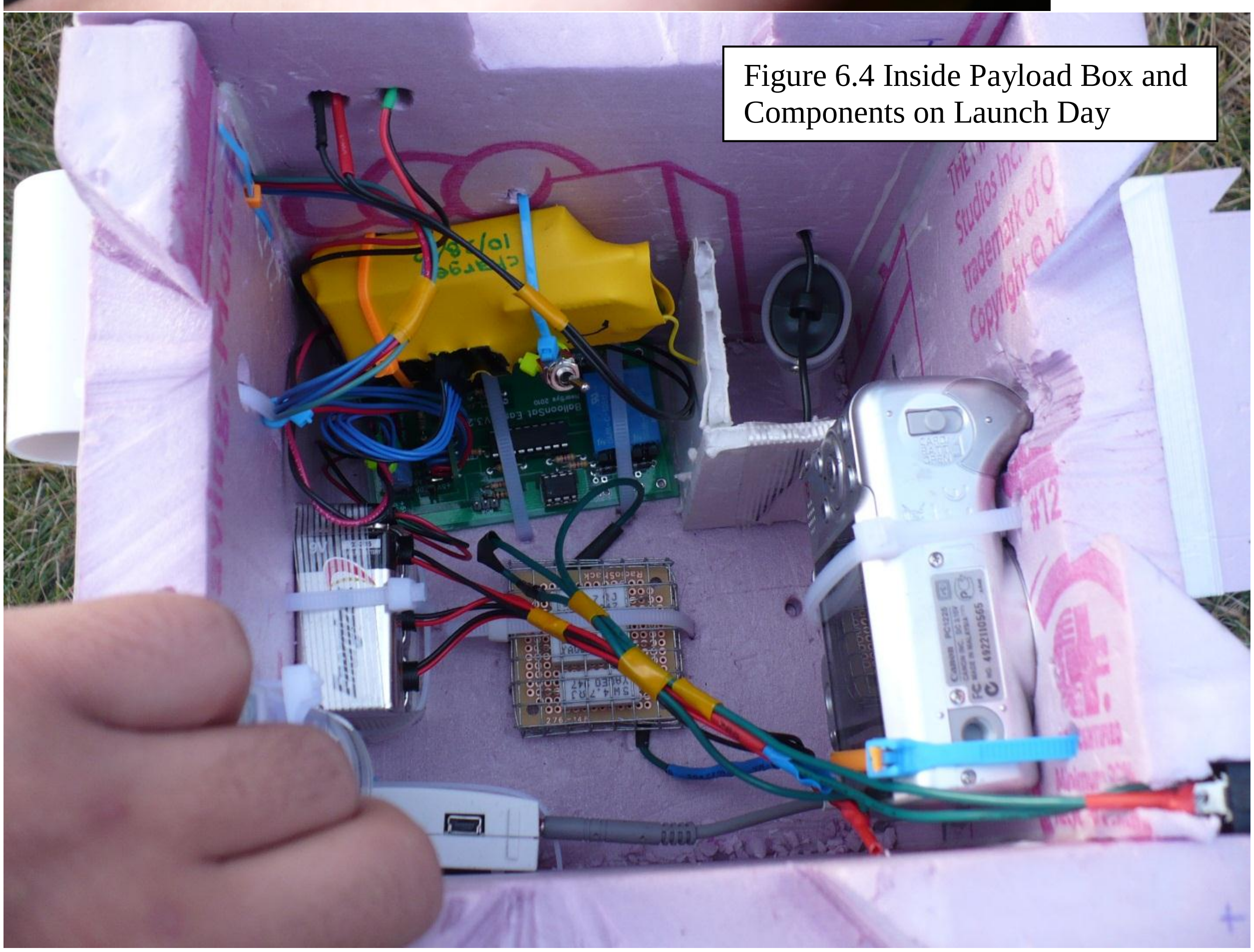


Figure 6.4 Inside Payload Box and Components on Launch Day

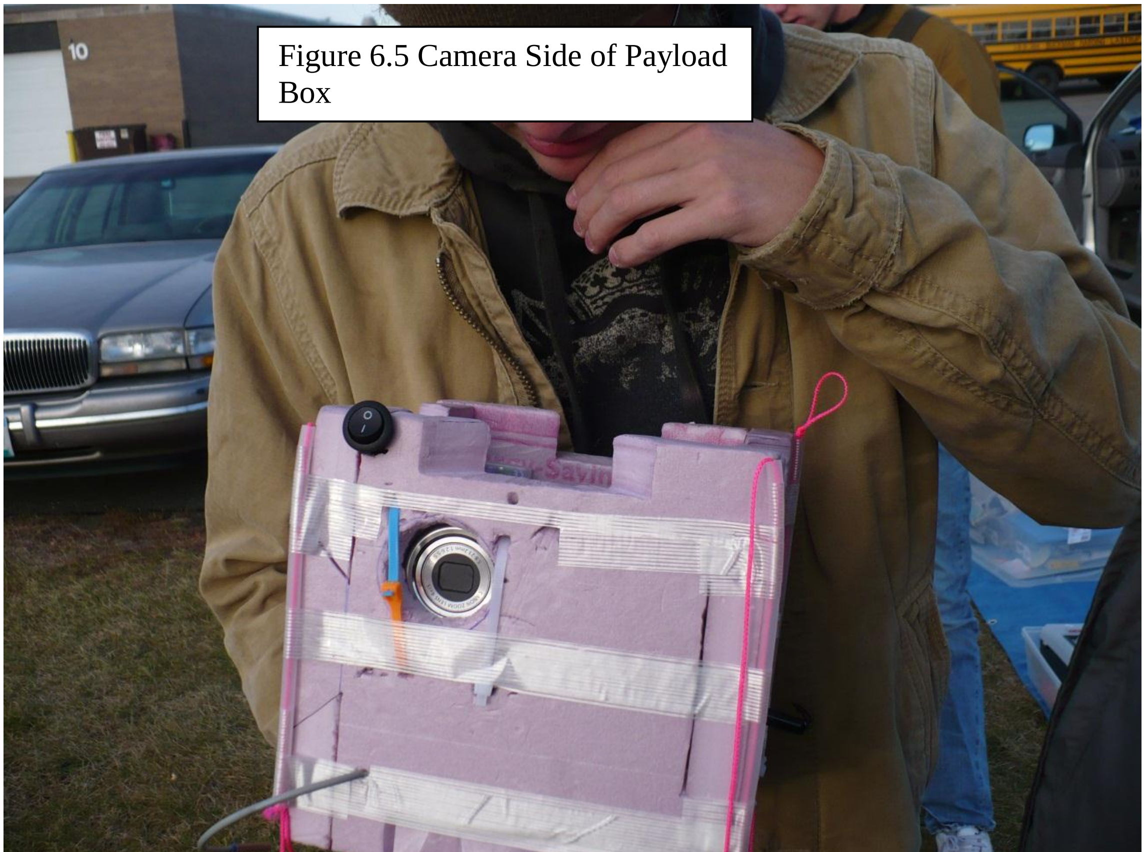


Figure 6.5 Camera Side of Payload Box

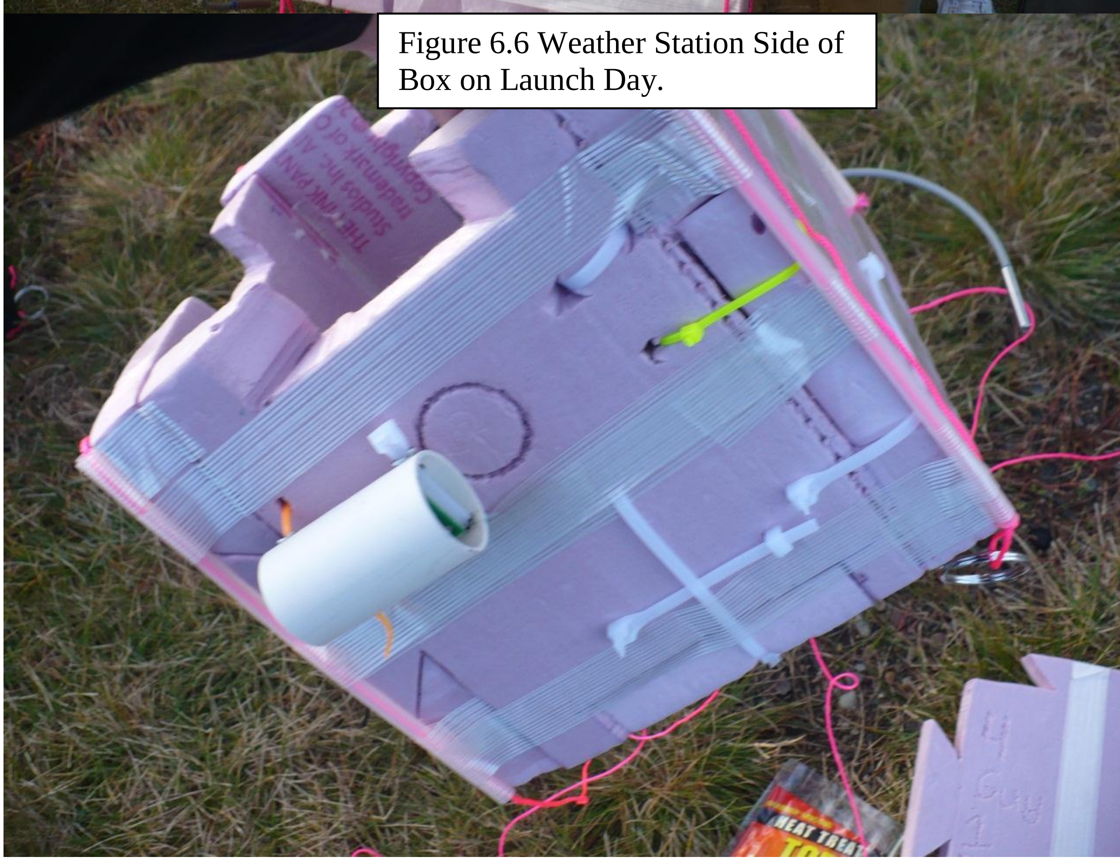


Figure 6.6 Weather Station Side of Box on Launch Day.

7.0 Test Plan and Results

Tests

- Cold Soak Test - Passed
- BSE Test - Passed
- Shock Test – Passed
- Yank Test – Passed
- Zigbee Test – Passed
- Camera Test – Passed
- Weight Test - Passed

There are a number of tests that are performed in respect to this project. These tests are separated into two categories data tests and functional tests. Data tests are tests performed before construction for the purpose of collecting data on an idea, experiment, or part. Functional test are performed on the constructed payload and its contents with the purpose of testing how well it performs constructed and catching any potential problems.

Data test that may be performed are: Styrofoam strength test, battery temperature minimum test, doving joint test. The purpose of the Styrofoam strength test and the doving joint test are to get a measure at how strong of materials and joints the payload box is made of. In the case of the doving test, the test will help us decide on the construction of the box. The battery temperature minimum test serves to tell us what temperature we need to keep the interior of the box.

Functional tests that may be performed are: overall box strength/integrity test, box and parts temperature test, harness integrity test. The purpose of the box strength/integrity test is to see if the box is strong enough to withstand the forces that will influence it during ascent and descent. The results from this test are essential because they will dictate if changes need to be made to the payload box. The second major test is the box/parts temperature test. This test consists of taking the box as it would be on launch day and putting it into at chamber that will simulate the temperatures that the box will be exposed to during its flight. If all the parts on the interior and the exterior work and continue to function at all temperatures then its chances of performing as intended in near space are better. A final test that will be conducted is the yank test. Basically this is a strength test to see if the harness will detach from the box during flight and if the components are well secured.. Failure during this test will mean redesign or strengthening the harness system and/or strapping contents down more securely.

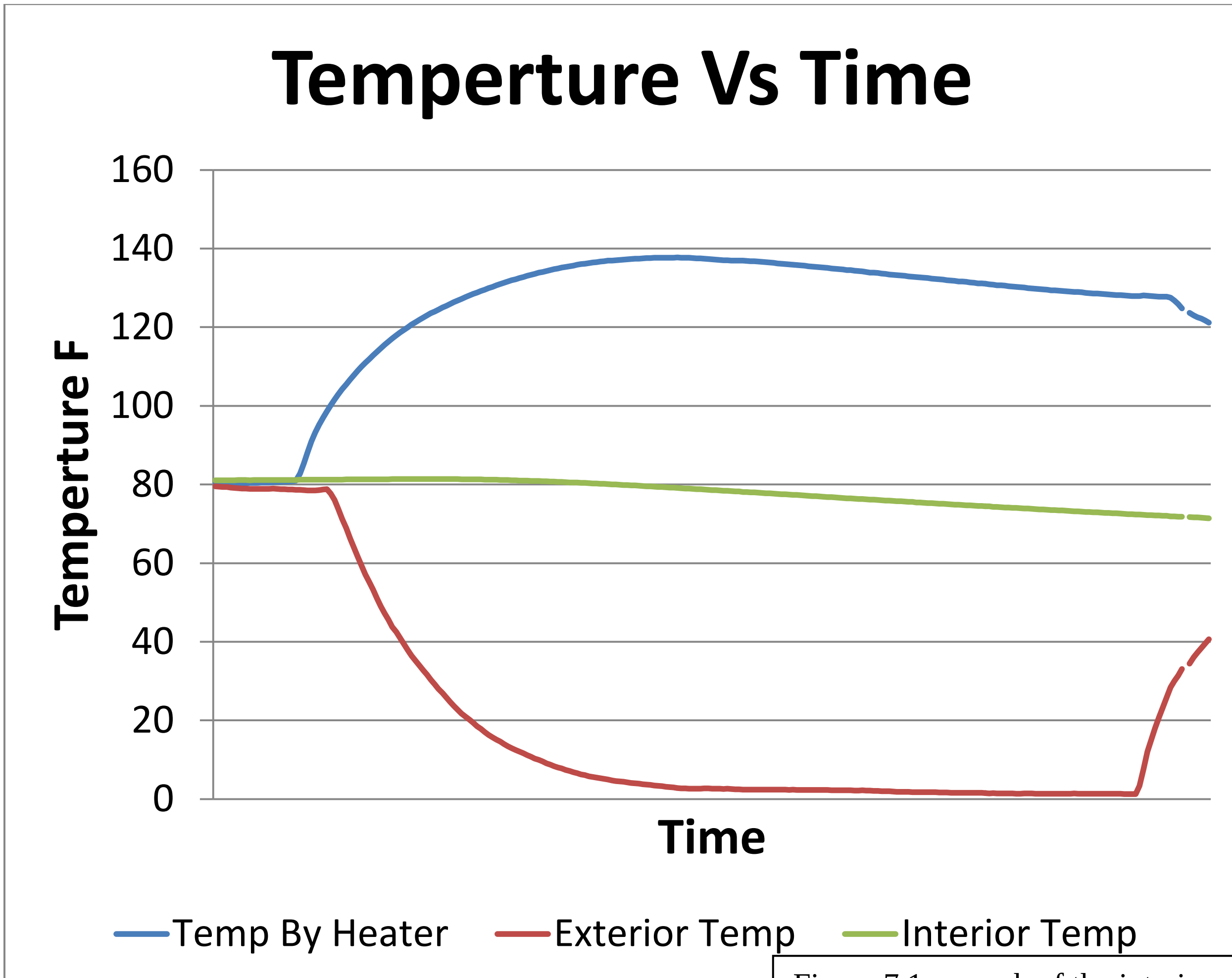


Figure 7.1 - graph of the interior temperature of the payload box during it's cold soak test.

The above figure 7.1 is a graph of the interior temperature, exterior temperature, and temperature near the resistance section of the heater circuit. By analysis of this graph we can see that the temperature retention of the box is adequate for the temperature we expect to encounter. The graph also shows the functionality of the Hobo and that the interior temperature is adequate to sustain the hobo's systems.

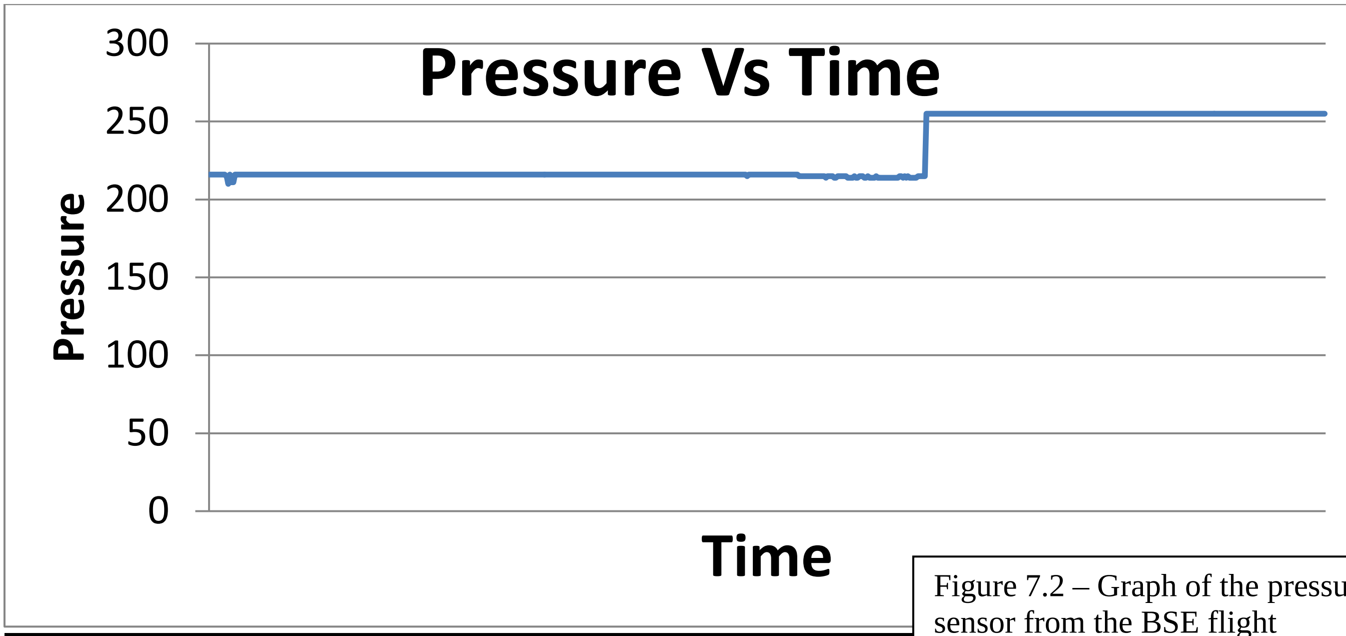


Figure 7.2 – Graph of the pressure sensor from the BSE flight computer. **Memory has a preset value of 255

Figure 7.2 shows the functionality of the weather station's pressure sensor and the functionality of the BSE flight computer. The slight bump in the negative direction in the beginning of the graph signifies a suction test on the sensor to test if it was performing. The slight warble of the line just before it assumes its preset memory value signifies the time it spent in the cold soak. Both of these put together signify that the pressure sensor has performed in the test environment.

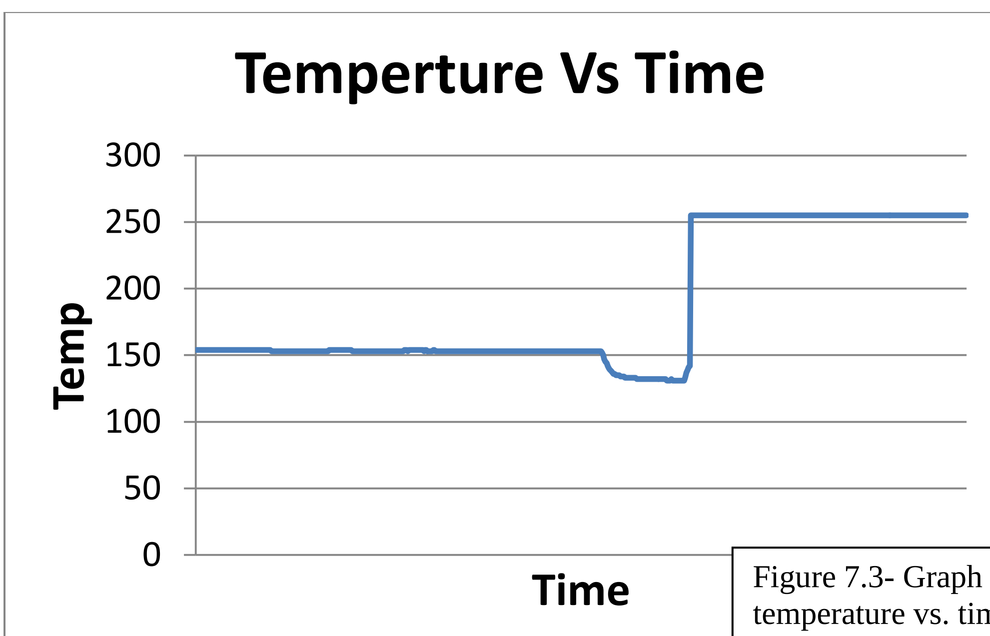


Figure 7.3- Graph of exterior temperature vs. time data for this graph was gathered before, during , and after the cold soak test.

Figure 7.3 is a graph of the data gathered from the weather station's temperature sensor. The data was gathered before during and after the payload box's coal soak test. Analysis of the graph leads us to two facts. These two important facts are the functionality of the sensor and the functionality of the sensor in its target environment. At this point a note must be made that the temperature scale that the sensor runs off of is one similar to the Kelvin scale, so the zero on the graph represents absolute zero. The constant temperature that the graph shows through most of the graph is an indicator of the regular functionality of the sensor. That is because the air temperature of the room we were in was constant. Once placed in the cold soak the temperature shifts in the negative direction as anticipated and the sensor continues to function until it is take out and turned off. This proves the functionality of the sensor at the target temperature.

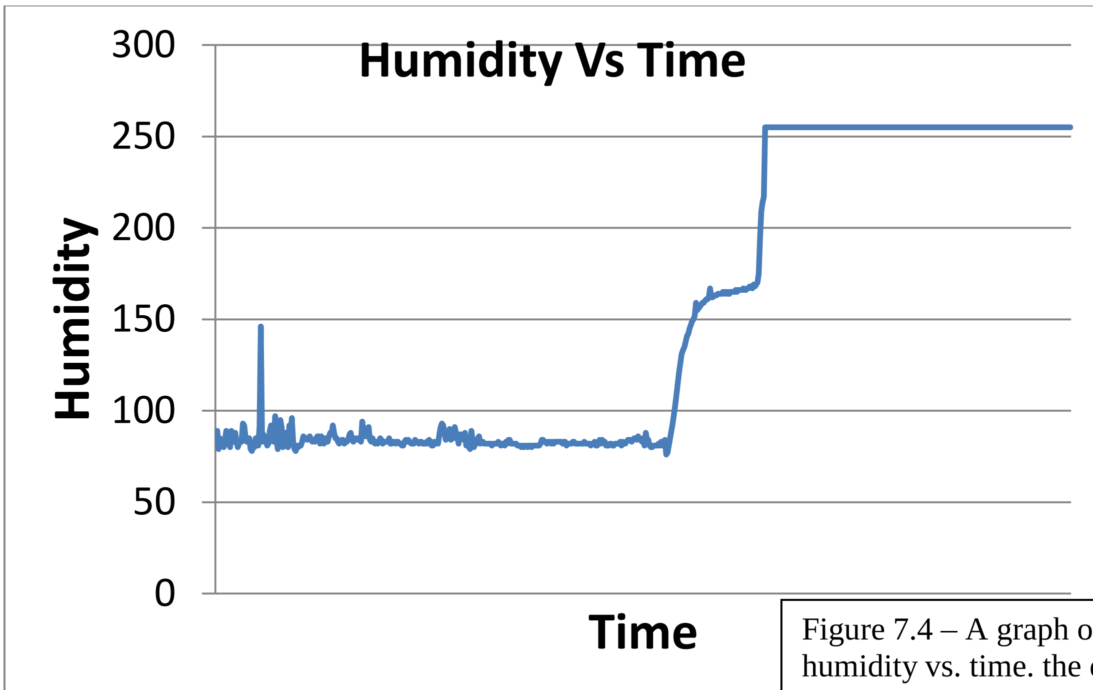


Figure 7.4 – A graph of the relative humidity vs. time. the data for this graph was gathered before during and after the cold soak test.

Figure 7.4 is a graph of the weather station's relative humidity sensor. This graph shows the sensors general and temperature specific functionality. By analysis of the graph, we see that in the non-cold soak environment the sensor function and spiked when it was introduced to a moist area. To expose it to moisture it was breathed on or a piece of damp paper was placed over the sensor. Once placed in the cold soak, the sensor continued to function and it read an increase in relative humidity which is attributed to the sublimation of the dry ice.

8.0 Expected Science Results

From this flight, we are attempting to gain data to test certain hypotheses about the environment of near space and how it affects certain variables. This section outlines our hypotheses. In order to do so, we must first have a reasonably clear picture of near space. Paul

Verhage, the author of the textbook *Near Space* defines near space as the region of Earth's Atmosphere between 75,000 and 330,000 feet above Earth's surface. Thus, it is the region above where airplanes fly yet that is not yet considered outer space. Although near space is not technically considered to be in outer space, it has similar conditions. To begin, temperature in near space is far less than that in the troposphere in which we live. According to NASA, the average temperature at sea level is 17 degrees Celsius. As altitude increases and we ascend through the troposphere, temperature begins to decrease. This relationship between altitude and temperature is known as the temperature lapse rate. Within the troposphere, the lapse rate in temperature is estimated to be about .65 degrees Celsius/100 meters. Or, for every 400 or so feet we rise in the troposphere, the temperature drops one degree Celsius. Because of this, the temperature will continue to drop until it reaches about -60 degrees Celsius at a region called the troposphere. This layer appears at around 9 miles above sea level, depending on how far one is from Earth's poles. Past this layer, temperature stays constant for awhile and then rises steadily as one ascends through the stratosphere. The temperature can reach up to 0 degrees Celsius at 31 miles above sea level. Past this point (the stratopause), the temperature decreases again. However, our experiment will not be able to ascend past the stratopause. Figure 8.1 shows how temperature varies with altitude.

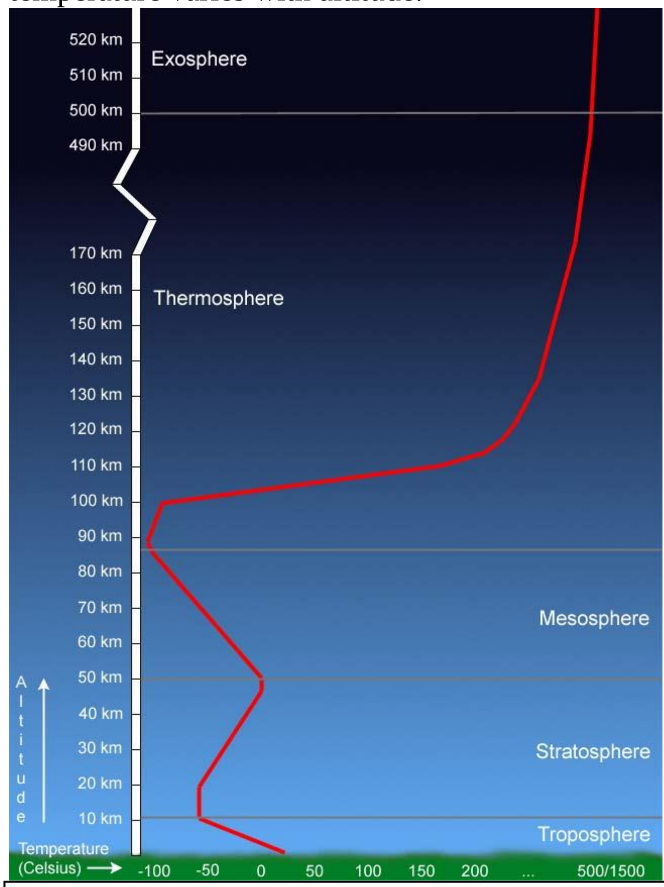


Figure 8.1: this graph shows the layers of the atmosphere and how temperature varies with altitude. http://www.windows2universe.org/earth/Atmosphere/layers_activity_print.html

Additionally, pressure decreases with altitude in a relationship known as the pressure lapse rate. Unlike temperature, pressure monotonically decreases in an asymptotic manner. Figure 8.2 shows how pressure decreases rapidly with altitude. These results indicate that near the stratopause, at 47 km above sea level, the atmospheric pressure is only about one percent of that at sea level.

Geopotential Height	Pressure	Density
(km)	*(hPa)*	*(kg/m^3)*
0	1013.25 00	1.225
11	226.3206	0.364
20	54.7489	8.803E-02
32	8.6802	1.322E-02
47	1.1091	1.428E-03
51	0.6694	8.616E-04
71	0.0396	6.421E-05

Figure 8.2: the table displays how air density and pressure varies with height above sea level.
http://mtp.jpl.nasa.gov/notes/altitude/StdAtmos1976.html

In his textbook *Near Space*, Paul Verhage estimates that with the type of balloon we are using, we can expect to travel up to between 80,000-100,000 feet above sea level. So, during this journey, the payload box will experience a drop in temperature to nearly -60 degrees Celsius, followed by an increase up to around -30 or -20 degrees Celsius. The box will also be exposed to a pressure drop down to nearly one-hundredth of that of sea level. These environmental changes are what are used to predict our expected results.

From the onboard weather station, we would expect that the temperature and pressure readings will match those of previously collected and accepted data from these regions. Because we are attempting to maintain a temperature inside the payload box, if all heating methods work effectively, the temperature probe inside the box is expected to read values considerably higher than those outside the box. Ideally, the temperature would exceed the freezing point of 0 degrees Celsius. As we rise in the atmosphere and enter the cloud layer, it is expected that relative humidity levels would rise. Then, after the clouds are cleared, it is expected to drop off slowly. Relative humidity is measured as a ratio of how much water is in the air to how much the air can hold. Because colder air cannot hold as much moisture, it is plausible that relative humidity would vary in a manner similar to that of temperature. First, it would decrease, perhaps even down to a 5% relative humidity level. Then, it would rise to up to an average of 55%, level out and drop to near 45% before the balloon bursts. These expected levels are based upon data found at http://www.physics.umt.edu/borealis/RH%20Lab%20Report_06.pdf. It was taken by students performing an experiment very similar to this one.

From the still camera, because we are verifying the altitudes of different features of the atmosphere, we expect our results to match those of previous experiments. See figure 8.1 for expected altitudes of layers of the atmosphere. We also expect to see the curvature of the Earth near the end of the flight at an altitude of 60,000-80,000 feet.

From the accelerometer experiment, we expect that the acceleration of the unbounded accelerometer will be much more chaotic than that of the restrained accelerometer. Because the purpose is to observe the effects of a restraining system on acceleration, we hope to create a system that creates a relatively constant acceleration near that of the gravitational constant g=9.8 meters per second squared. For the unrestrained accelerometer, the acceleration is expected to vary greatly with time.

9.0 Launch and Recovery

Here is the account of the team Four Guys 1 Box on the launch and Recovery of their payload box on Saturday Oct 30, 2010.

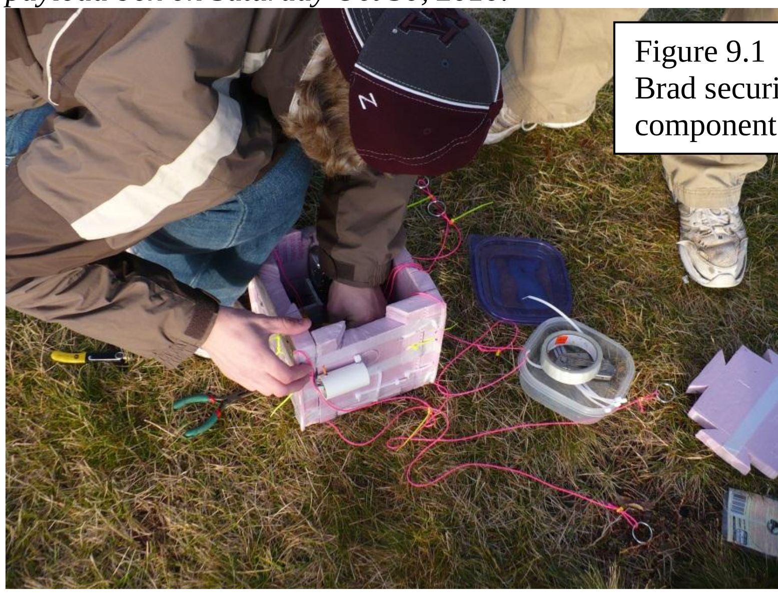


Figure 9.1
Brad securing the final components before flight

It was a chilly October morning when we arrived shuffling in by ones, twos and threes at Shepard laboratory. We all were loaded up on caffeine that morning struggling to stay awake because each member of the group had slept little the night before in anticipation of the launch. While we waited to leave in the vans, the extent of our sleep deprivation became evident as our hold on our behavior started to slip. Suddenly the funny became hilarious and as we piled into the vans to travel to our launch site the mood was very jovial. The driver of our bus was a dear lady who provided her passengers with muffins. Perhaps now she is reconsidering the choice to provide us with muffins, for the muffins became central to many jokes. The whole van was howling with laughter as the muffin bag was stolen and reclaimed, and the driver was teased that she had laced the muffins with some unknown substance. Now looking back on the scene I think that if there was any truth to the claim that the muffins must have been laced with some sleeping drug. The more reasonable answer would be that exhaustion finally took the riders because shortly after eating those muffins the majority of us had fallen asleep. Those who were able to stay awake for a while longer promptly started teasing our driver about her fine driving ability and anything else that proved to spark a reaction. Eventually everyone on the team drifted off to sleep.

Figure 9.2
The site of launch

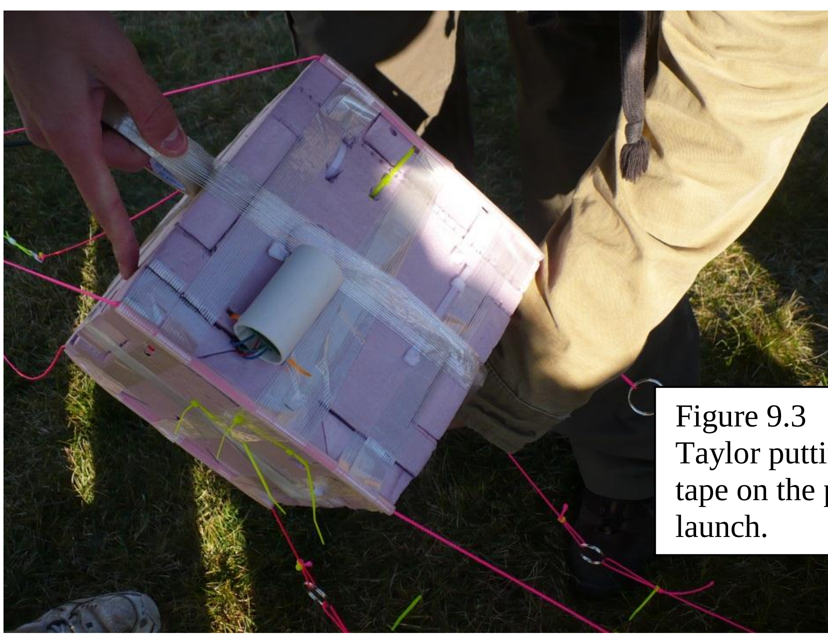


Figure 9.3
Taylor putting the final wrap of tape on the payload box before launch.

We were awakened upon arrival at our launch site. The launch site was located behind the high school of a town near St. Cloud. The class filed out of the van and after receiving a small speech on the duties that needed to be accomplished we broke off and huddled around our payload box. The first thing that needed to be done that morning was a check on the functionality of the box's components. This basically meant we checked if the parts were working by turning them on and looking for indicators. In the check of the heater circuit, we placed our hand on the resistors in the circuit to see if they were heating up like they should be. We checked the flight computer, Hobo, and accelerometers by seeing if their indicator lights were flashing like they should. The camera was also checked to see if it was warm enough to function. In the course of checking these systems it was noticed that the zigbee radio was plugged in. after a few questions were posed It, was discovered that the zigbee's battery had been plugged in for the duration of the night. This had drained the battery and so the zigbee needed to be replaced. Replacing the zigbee meant the removal of the zip ties that secured it to the payload box and then reapplying zip ties to secure the replacement. This procedure was made more difficult by the fact that the zip ties became brittle at the cold morning temperature. With the zigbee back in place, a hand warmer was placed over the camera to try and keep it warm until launch time when the heater circuit would take over that responsibility.

With our duties done for the time being, we walked around to see the other group's payloads. To our minds, they all seemed like solid designs with the exception of the payload box of Galactic Gophers. Their design called for a boom to be attached to their box so that they could receive visual data with which they would calculate the volume of a balloon affixed to the end of the boom. We from Four Guys 1 Box were skeptical of this boom to the point that bets were places as to how long the boom would survive flight.

The groups were called in once again and everyone split up to cover their launch day responsibilities. Brad, being our balloon filling specialist, went off to cover his duties there. Those duties consisted of an exciting time of standing around trying to look significant while the wind pushed the balloon away from him. Needless to say he did a good job. All the while this was going on our photographer Salman was dancing around Brad snapping photos of him working and of the group assigned to the care of the balloon doing their job. He eventually moved from that subject to the line of payloads laying on the group with the various group members huddled around doing last minute preparations. As the time to launch dwindled, Taylor started doing a final check of the box. When he was satisfied that the box was ready he sealed up the box. Now everything was ready for launch.

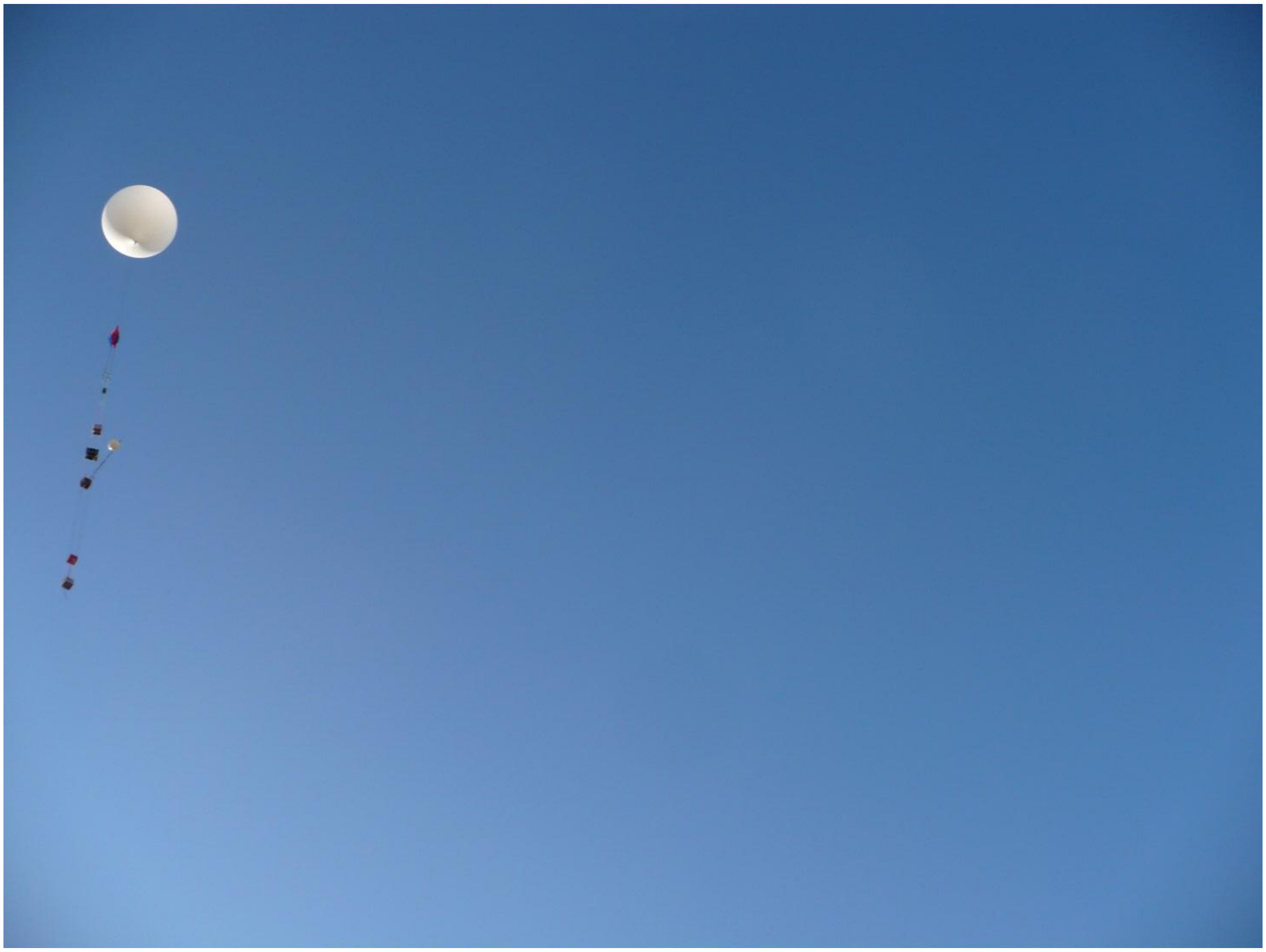


Figure 9.4
Photograph of the balloon and payload moments after launch

Figure 9.5
Picture taken from payload camera moments after launch

With the balloon filled and the payloads ready, it was time to launch the balloon. Hand over careful hand the balloon was let out. Once the last payload was released, the balloon quickly ascended into the sky. The many faces of the many groups turned up to watch their effort filled payloads float off into the sky. In that moment, many of us felt like fathers watching their children leave for kindergarten for the first. It was a touching moment.

As touching as it was, we had to get onto the road to follow our children. Using APRs & Stratostar tracking systems we followed the payloads as the floated above the earth. We knew roughly where the payload was going to land from choosing the launch spot and knowing the affecting variables. The payloads were to travel quite a distance and for those of us not being floated by balloon it meant a considerable car ride. This ride was much like the ride out to the launch site. The majority of us slept our way through the ride and those of us who didn't sleep had a conversed gaily with the drivers.

For one reason or another, the balloon did not land where we had predicted. It landed an hour away from where we predicted, and this extra hour was just enough extra time to force us to abandon a personal recovery of the payload. The group was looking forward to retrieving the box. Taylor even joked that he was looking forward to a swamp or lake retrieval just to make it interesting. Instead a vanguard group recovered the payload and returned it to us. From their account, we know that balloon, parachute, and string of payloads landed in a tree. Also the terrain of the area was harsh such as a swamp, a lake, or a marsh would be. Luckily, it was relatively easy to pull the boxes out of the tree and none of the payloads seemed to have suffered any damage. The exception of this was the box of Galactic Gophers. Their boom miraculously survived flight only to be damaged during retrieval. Once we learned that the payload was going to be recovered by someone else, the vans turned around and drove us back to the university.

Figure 9.6
Heavenly image taken by the payload camera during flight

We learned later of the recovery and status of the payload box. The payload box was in roughly in the same condition after flight as it was before flight. During the flight data showed some minor sensor failure which we attribute to faulty materials. The landing caused the greatest amount of damage, most being to the exterior.

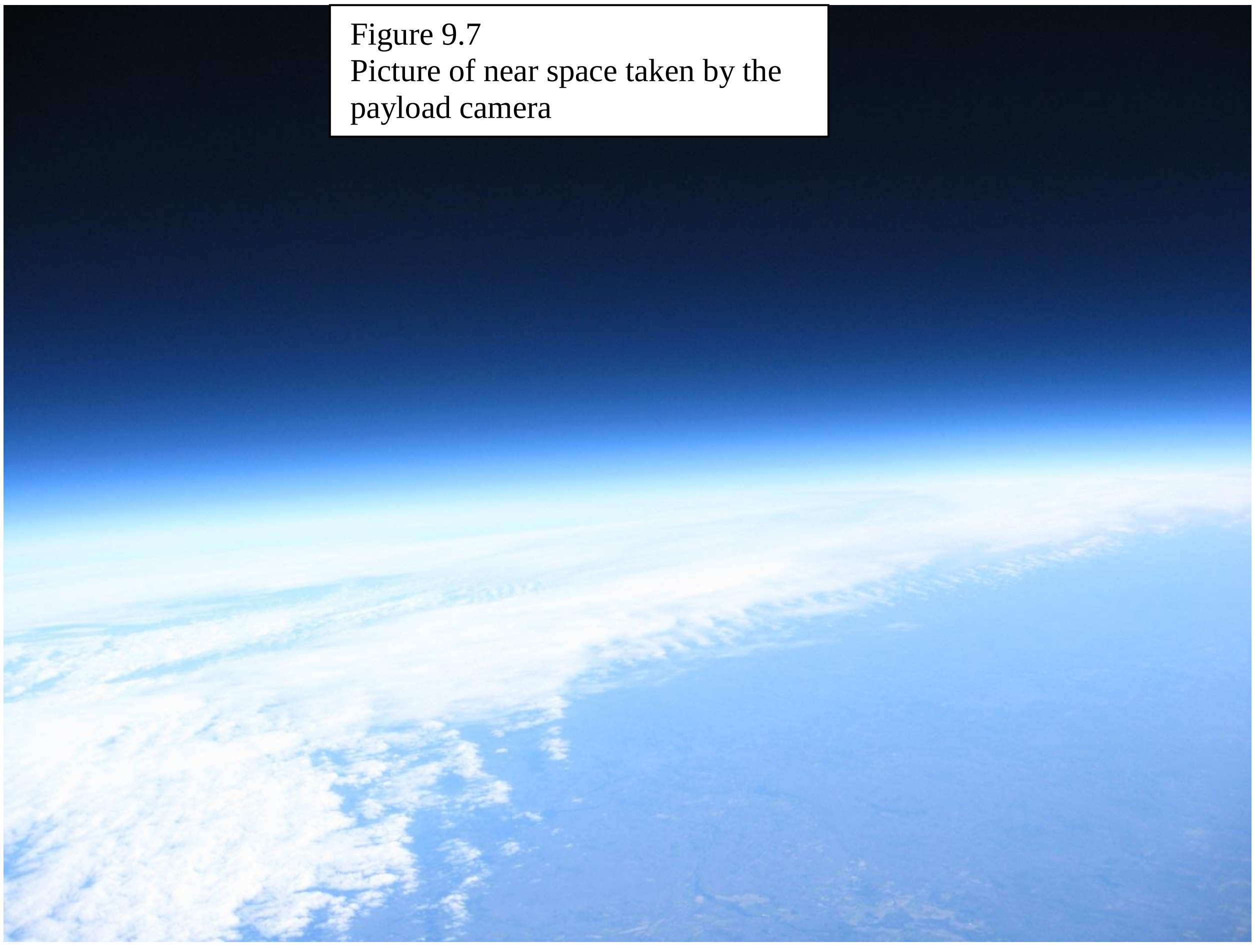


Figure 9.7
Picture of near space taken by the payload camera

10.0 Results and Analysis

This section pertains to the data gathered from the sensors on board the payload as it traveled through near space. Analysis is done specific to the sensor even though theories may be stated to connect data and conclusions. This is done to reduce the chance of making a faulty conclusion due to inaccurate data. It must be noted that for all altitude calculations the following equations provided by Professor Flaten were used.

For $0 <= t < 20$ min ("ascent phase 1"): $A = (1076.9 \text{ ft/min})*t + 1223.4 \text{ ft}$

For $20 <= t < 112$ min ("ascent phase 2"): $A = (737.1 \text{ ft/min})*t + 8304.3 \text{ ft}$

For $112 <= t < 146$ min ("descent phase"): $A = J*t^4 + K*t^3 + L*t^2 + M*t + N$ where

$J = +0.10645 \text{ ft/min}^4$

and $K = -57.761 \text{ ft/min}^3$

and $L = +11763 \text{ ft/min}^2$

and $M = -1067100 \text{ ft/min}$

and $N = +36450000 \text{ ft}$.

The hobo recorded three sensor values: interior temperature, exterior temperature, and relative humidity. Figure 10.1 shows a graph of the interior and exterior temperature vs. time. This is a relatively unimportant graph in itself because besides launch you cannot recognize critical points in the flight or determine trends in altitude. The importance of this graph is that by comparing the interior temperature to the exterior temperature we prove the success of constructing a functional payload box and heater circuit.

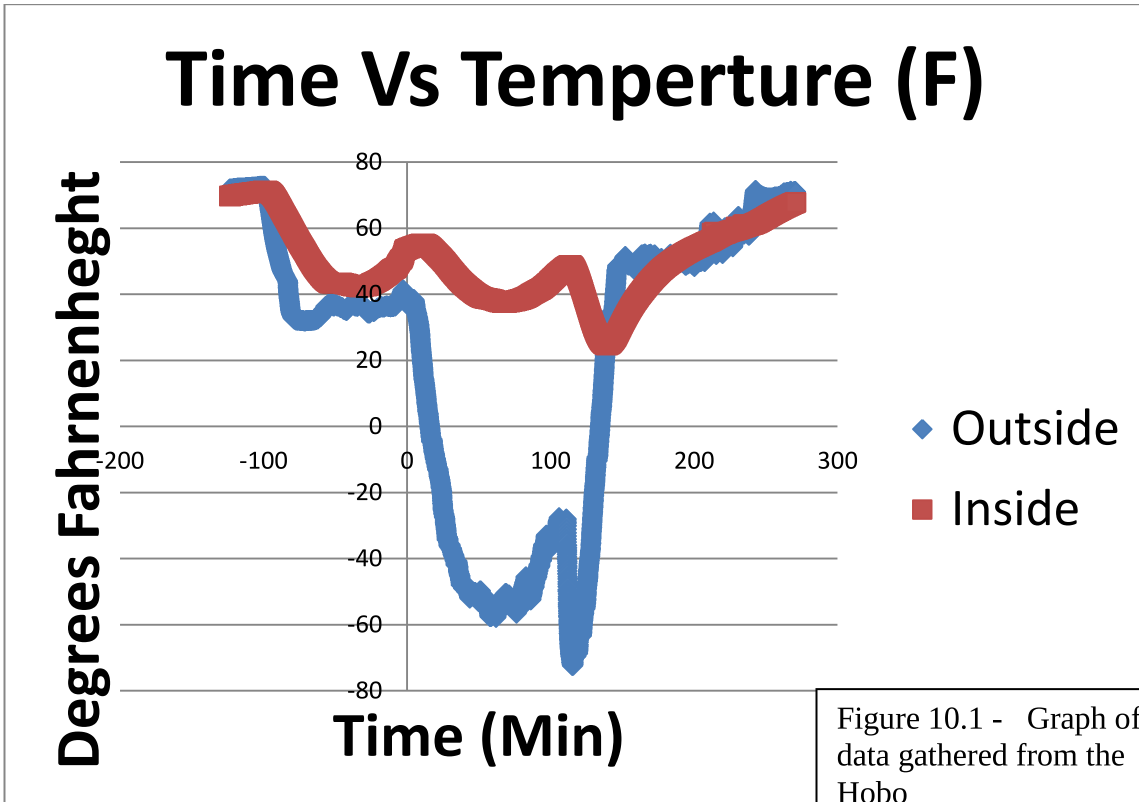


Figure 10.1 - Graph of the data gathered from the Hobo

Figure 10.2 is a graph of the interior and exterior temperature data in respect to the altitude at which it was gathered. The exterior temperature follows a trend in which the exterior temperature decreases at a seemingly linear manner till the 35000 ft. From 35000 ft., the exterior temperature decreases at a less drastic rate until the height of 700000 ft. After 70000 ft., the temperature increases till burst where it is approximately -23 degrees Fahrenheit. The decent follows the same trend as the ascent but with a positive translation in the temperature. This is most likely due to two things. One, the altitude is probably skewed by a small amount. This coupled with the fact that the flight started in the morning while the sun's radiant energy was partially blocked.

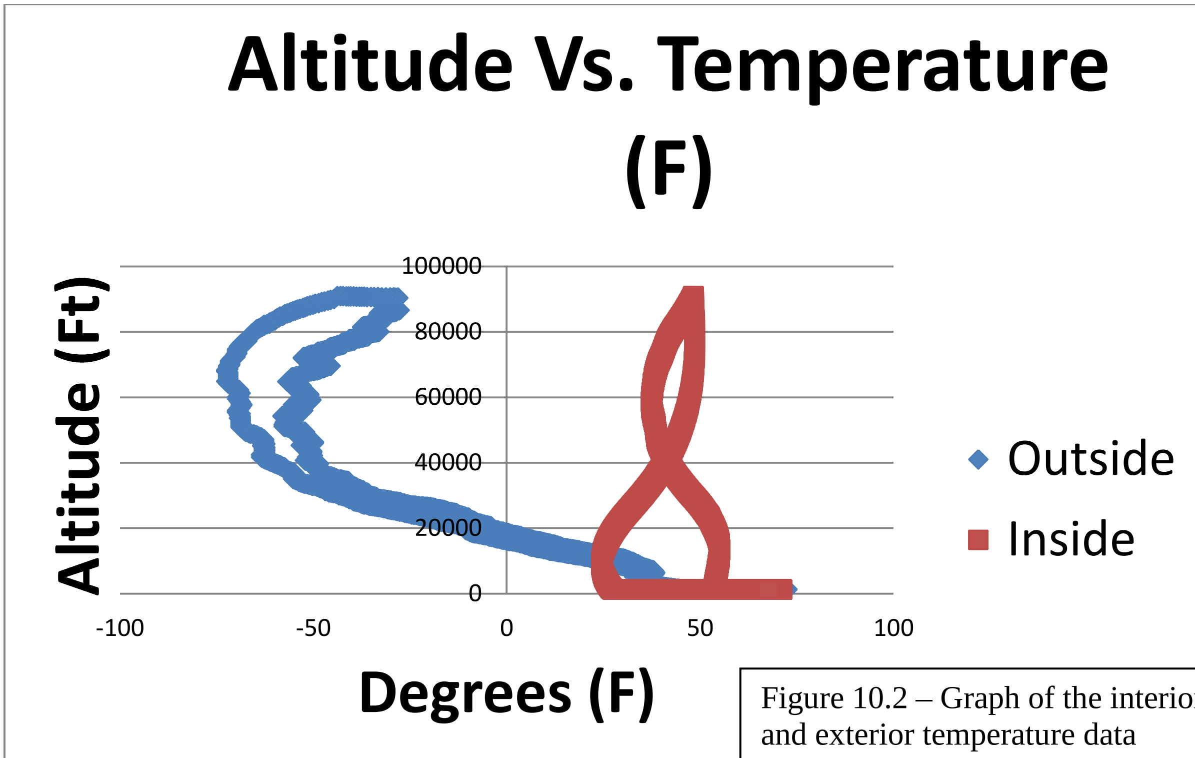


Figure 10.2 – Graph of the interior and exterior temperature data gathered by the Hobo vs. Altitude

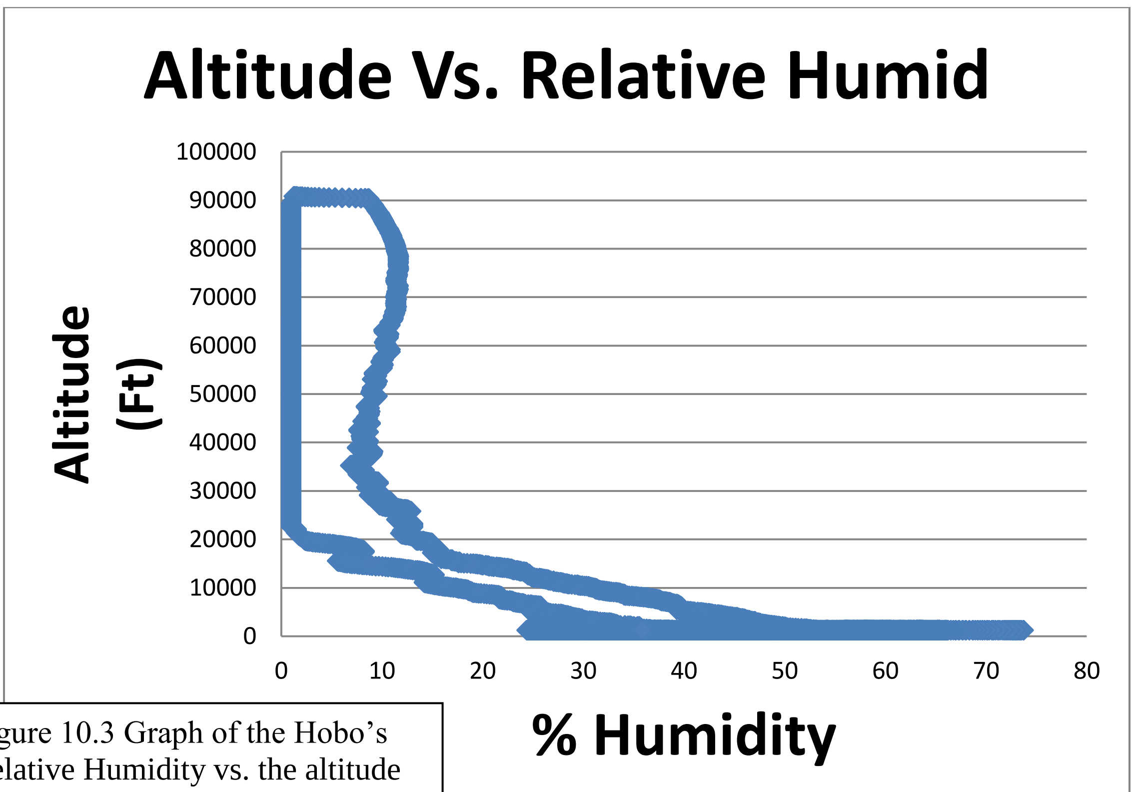


Figure 10.3 Graph of the Hobo's Relative Humidity vs. the altitude at which it was gathered

The final sensor data gathered by the Hobo is relative humidity. Figure 10.3 is the graph of relative humidity vs. altitude. In this graph we can see the overall trend that relative humidity decreases as altitude increases. We can also identify the cloud layer at near 15000 feet. This is identified in the graph by an increase in relative humidity followed by a sharp decrease. One thing that must be addressed in this graph is that the sensor suffered a failure over a period of time. The graph's values of zero from 21000 feet to 90000 feet are a result of this failure.

BSE Data Results and Analysis

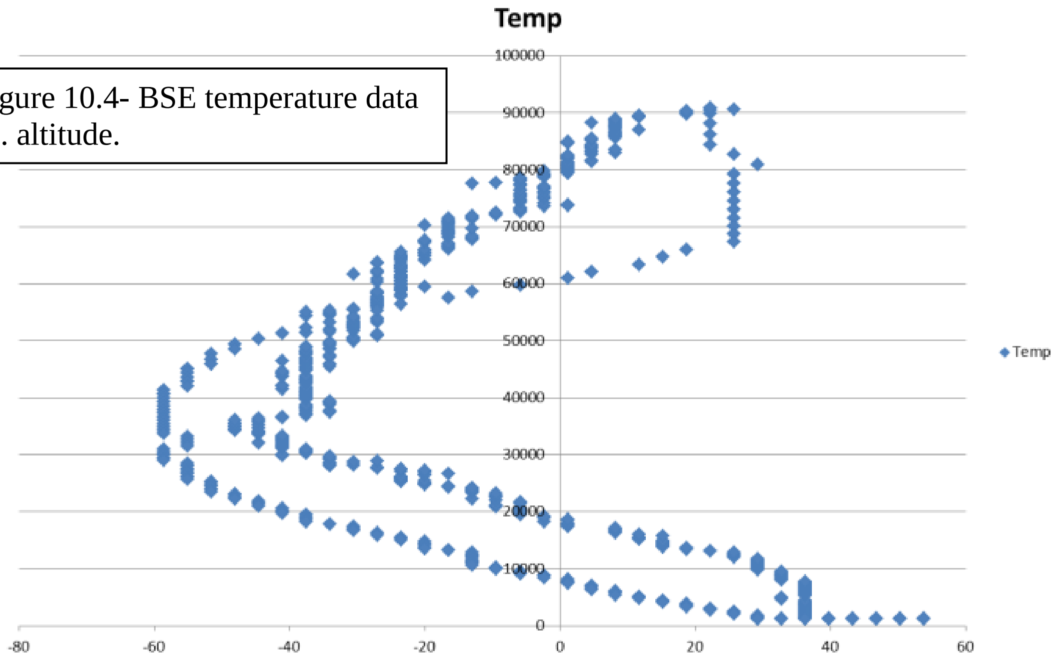


Figure 10.4- BSE temperature data vs. altitude.

The temperature data exhibits the expected overall trends, however, it has a few irregularities. In general, the temperature falls as time goes on, and (as shown by the altitude vs. time graph) as the altitude increases. This trend is due to the decreasing pressure and increasing distance from the heat of the earth. This continues up until a point we discovered to be when the balloon had risen about 40,000 feet. After this point, the temperature began to increase again and continued increasing up until the point of burst. During this time of temperature increase, there was a large amount of seemingly overlapping, and slightly scattered data. The explanation for this is unknown but it does makes sense for there to be more data points as the balloon rises and less as it falls due to the relative speeds of the ascent and descent. The descent data followed a similar pattern followed a similar overall pattern, with a few differences. After burst it seems there was a large delay, in which the altitude dropped, but the temperature stayed mostly constant. The cause for this could be an error, either in data collection, or in our data conversions. Interestingly, following this delay, where the temperatures were higher during descent, the data points intersect and then separate again; the temperature then remains lower during the rest of the descent than it had been during the ascent. Another irregularity in the data is the large amount of variation in the temperature at ground level, or during the beginning and end of the data versus time. This however can be explained more simply. The balloon payload spent the largest amount of time at ground level, so this is the place where it was most affected by normal daytime temperature changes.

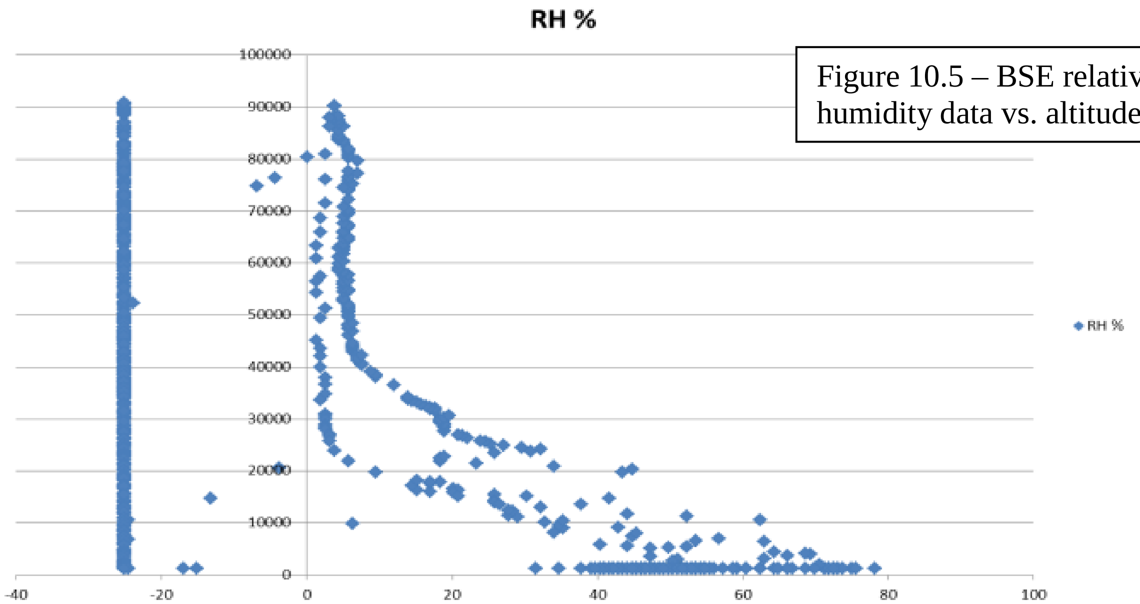


Figure 10.5 – BSE relative humidity data vs. altitude

Our relative humidity data has a large amount of scattered and "bad data". The "bad data" is the data points at which the BSE failed to take an accurate measurement and went to its default value. These points can be clearly seen as the vertical line in the negative portion of the graph. As a rough analysis, the relative humidity starts around 60% and levels off around 5% on the ascent, and follows a similar pattern on the descent. The data points collected below 30,000 feet are very scattered and seem almost random. When the altitude is at ground level, this might be explained by the moisture on the ground. Perhaps factors like dew or condensation. At higher levels, the scattered data could be due to moisture in the air (clouds). Some of the differences between the values during ascent and the values during descent could be explain by a delay in the readings or by weather related changes in the relative humidity that happened while the payload was in flight.

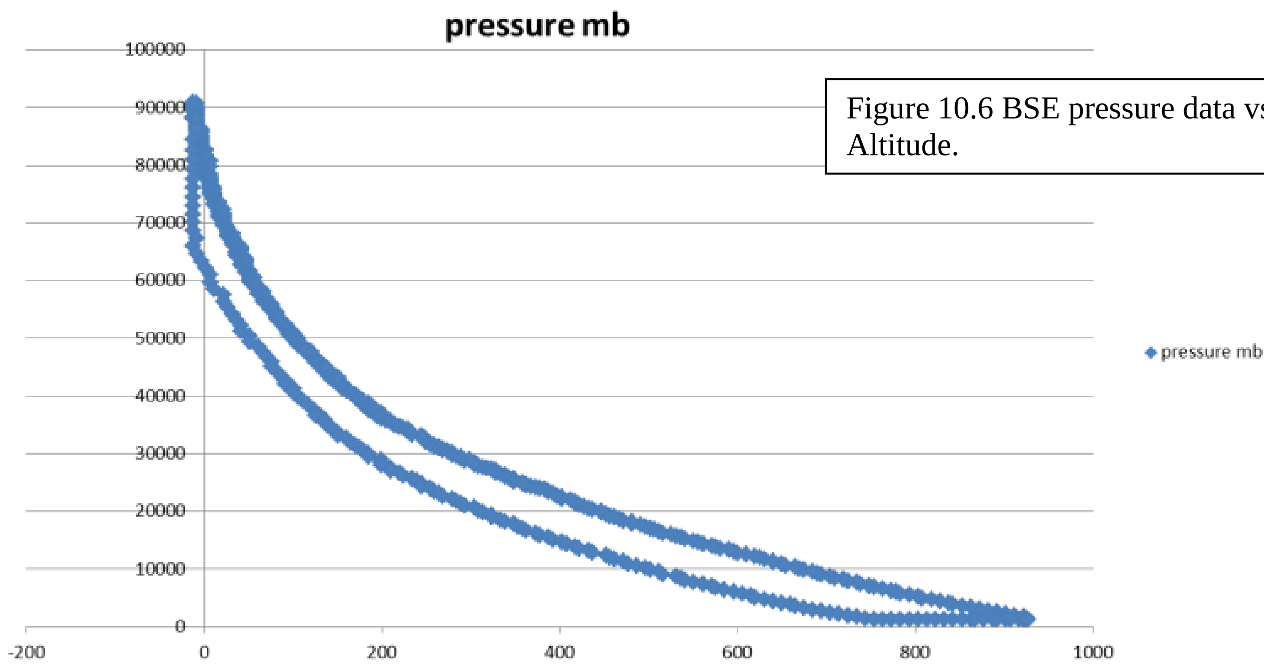


Figure 10.6 BSE pressure data vs. Altitude.

After converting our raw pressure data and comparing it with that of other groups we found out that this data was completely inaccurate and inconclusive. For this reason we decided to discard our own BSE's pressure data and use the pressure data of another group (Stark Industries). This data gave us a much nicer sample of accurate pressure readings, but still contains a few irregularities. This pressure data, as related to altitude follows the trends we would expect very well. The pressure decreases as the altitude increases. The rate of decrease in pressure actually decreases as the altitude increases, giving us a concave graph and showing that this relationship is non-linear. The pressure values apparently began between 800 and 900 milibars (it's difficult to tell exactly due to pre-launch and post-landing variation). The descent follows the ascent data very closely as it relates to altitude. The slightly lower values for pressure during descent could be explained by a delay in the reading of pressure during the rapid descent, or it could, partly, be that the atmospheric pressure had dropped by the time the balloon burst and began descending. An irregularity in this data is that as the values get close to zero, they continue and some reading show pressure below 0 milibars. This is obviously impossible and could have taken place due to the BSE's calibration not following what it needed to for the conversion to work properly or it could be partly due to instrument malfunction during the turbulent time following burst.

Accelerometer Experiment Results

In this experiment, both accelerometers were used, and both brought back relevant data. On each accelerometer, data was obtained for the x, y, and z axes of motion. Surprisingly, the x axis corresponded to the direction of payload motion, or the vertical direction. The y and z axes spanned the plane of Earth's surface. We can verify this by observing the value of constant acceleration during flight. Because the accelerometers take in force measurements, the plot showing a constant acceleration of 1g during flight (x-axis) was taken to be the in the direction of motion, as the other two plots have an acceleration of zero during flight.

After the data were obtained for each direction, the data for each axis on the restrained accelerometer was compared to the respective data on the control accelerometer. Ideally, we would have observed a significant reduction in acceleration in the y and z direction, as the restraining system was intended to limit any acceleration outside of the direction of motion. Acceleration in the direction of motion (x axis) was expected to be the same, as the ties were not expected to prevent the accelerometer from moving upward.

On the following page, plots of acceleration vs. time for each accelerometer in the y direction of motion are shown. Had our expectations been met and our restraining system been successful, we would have a significant reduction in the magnitude of acceleration for the accelerometer that was strapped down. However, as the figure shows, there was little to no change in the magnitude of the acceleration during launch, burst and recovery. This indicates that the ties used were not effective in preventing side-to-side vibrations. In fact, because the accelerometer was attached to the payload box, the system used would likely not be improved by tightening the ties; the vibrations of the box itself likely caused this acceleration.

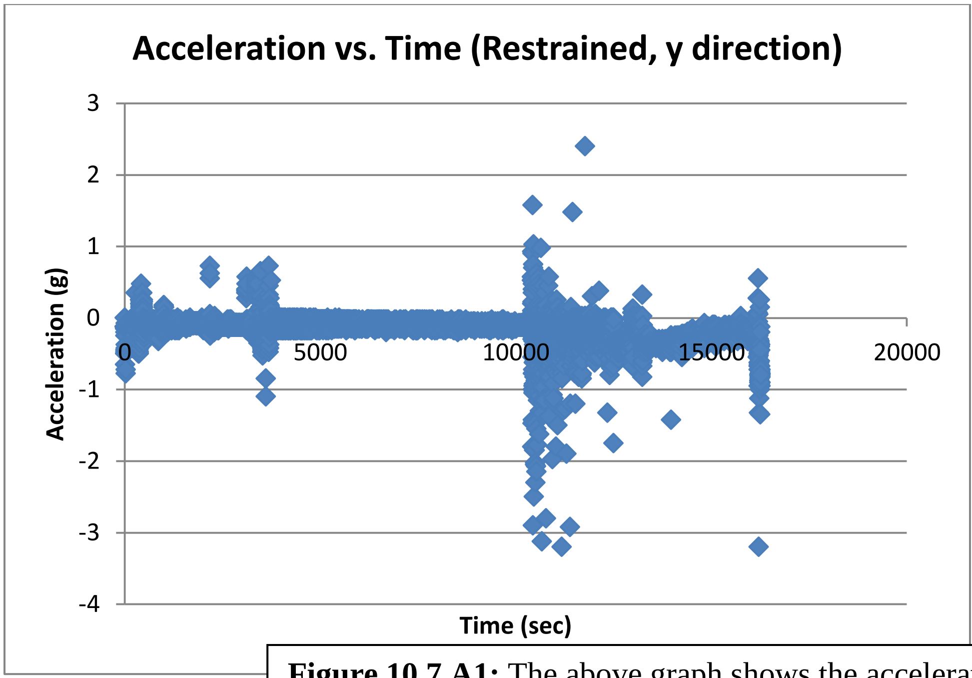


Figure 10.7 A1: The above graph shows the acceleration versus time of the restrained accelerometer in the y direction. Note that the acceleration is zero during flight and that spikes in acceleration correspond to different parts of the flight.

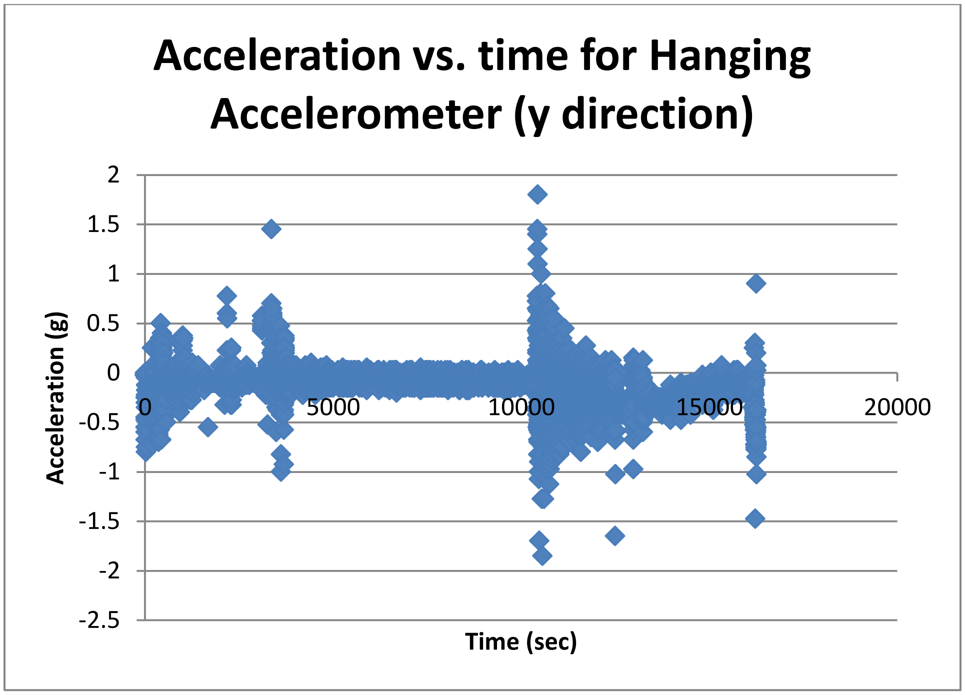


Figure 10.8 A2: The above graph shows the same data as 10.A1, but for the control accelerometer. Note that all of the same features are present and the graph follows a similar pattern. Unfortunately, the plot does not indicate a significant change in acceleration, as the values show essentially the same results.

information in these results. If we look at plots in the direction of motion, one can see a kinetic representation of what a payload box experiences during flight. From Figure 10.8 A3 on the following page, there are many features to note. The graph shows a good amount of acceleration which then levels off. This corresponds to the movement the box experienced before launch as the components were being turned on and the box was sealed. Then, the box experiences a spike in acceleration as the balloon is launched. This quickly levels out to an average reading of 1g. This continues throughout the flight, indicating that once a payload begins ascending, flight is relatively stable and constant. Then, the acceleration suddenly jumps to a much higher value. This shows the time of burst and the following chaos as the stack tumbles through the air. These readings were the highest of the flight, which indicates that the period of burst is the most stressful for the payload and its components. Then, the payload begins to descend. The acceleration is chaotic for a while, but it eventually centers on an expected value of -1g as the stack stabilizes in its descent. This marks the end of the relevant data plots. See the Figure below:

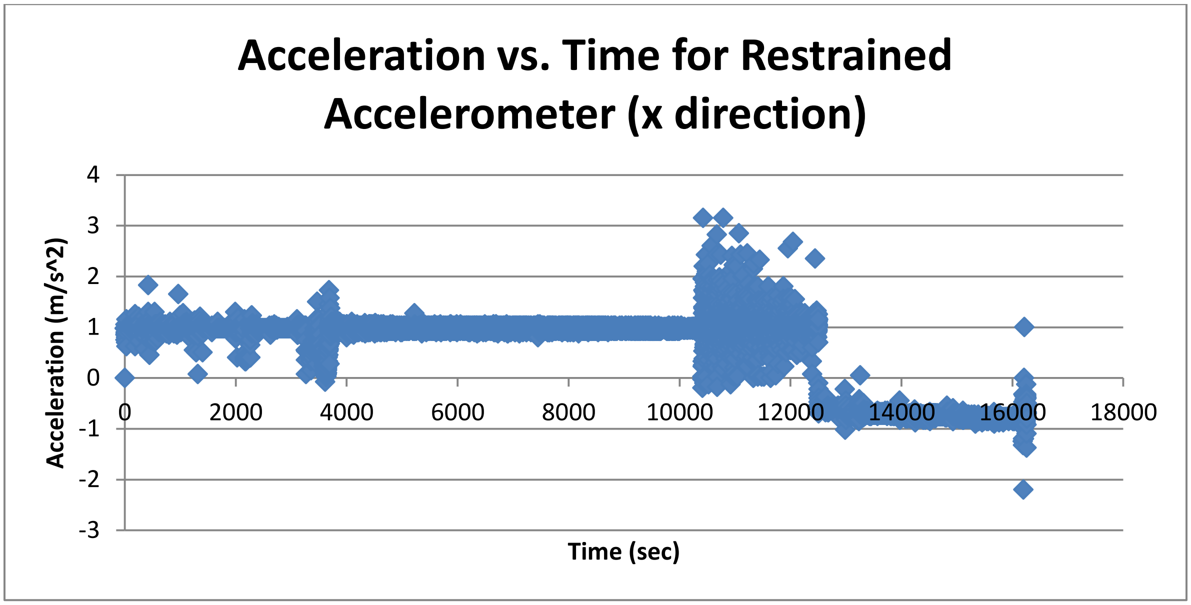
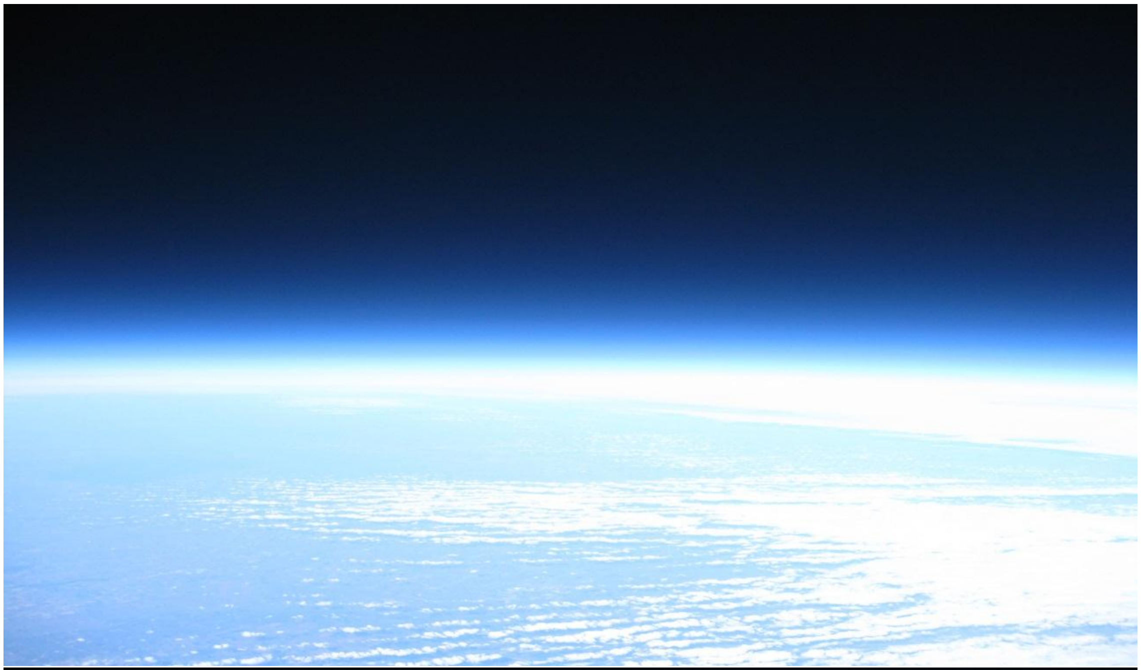


Figure 10.9 A3: This graph shows the acceleration versus time of the restrained accelerometer in the direction of flight (vertical or x axis). Note the many parts of flight that are indicated by spikes in acceleration on the graph.

To conclude, the restraining system designed for this experiment did little to prevent side-to-side acceleration, as shown in Figures 10.A1 and 10.A2. This was due to the ties being directly connected to the box; as the box vibrated, the accelerometers would as well. However, the data for acceleration in the direction of motion is not rendered irrelevant. Instead, one can look at this data to see what kind of motion a payload box experiences during flight. In fact, the changes in acceleration may be used to point out different parts of a flight and may be put to other purposes. For example, any materials put in a payload box must be able to survive the accelerations observed. If a payload box breaks down at 2g's, for example, a revision will be necessary to ensure the box will survive the balloon burst. If this experiment were to be repeated, we would suggest a different restraining system in order to create some significant change in side-to-side motion. If successful, the restraining system could then be used to more securely fasten other components of the box and ensure a successful flight.

Camera



From the photos and the camera experiment our group found that the balloons highest point was the stratosphere. The camera took some crazy pictures at it came down rapidly after the burst. There are some pictures that the camera took. Some of the pictures that we took were blurry and some were crystal clear. The pictures turned out upside down because the camera was strapped on upside down. When we received the payload box after the flight everything was intact and the camera wasn't damaged.

Some of the conclusions we came across in the camera experiment is that the highest out the camera went into was the stratosphere. A little mistake that we made was that the camera was placed upside down. It was a minor obstacle because all we had to do to correct that problem was to rotate the pictures around. I think that if we used a better camera we could have gotten some ore of the high quality pictures. Another thing we could have done is that programed the camera to take pictures every two seconds. We could have possibly caught the balloon burst. Overall the camera experiment well and we accomplished our goal of getting pictures of the earth's curvature.

The final picture our camera took

11.0 Conclusions and Lessons Learned

From the hobo and weather station sensors we learned various atmospheric characteristics. For temperature, we learned that temperature decreases/increases at near linear rates in accordance to altitude. There is a point about 75000 feet where the temperature changes from decreasing to increasing. We learned that pressure decreases as altitude increases, and that relative humidity also decreases as altitude increases in a characteristic way. From the accelerometer data that was gathered, the conclusion that was drawn was that the restraining system used did little to change the dynamic of motion that the accelerometer was subjected to.

If the group has the chance to repeat the process of launching a payload into near space the major thing that we would do is perform a more specific and reliable or interesting science experiment. A shielding experiment and a radiation experiment were suggested as possible experiments in the beginning of the class and it would be interesting to perform on of them. Another thing that might be changed is the design of the payload box. The design that was used in the current payload box served its purpose just fine perhaps even better than expected, but it was an unnecessary amount of work, and it would be more time efficient to not dove the payload box. Then again perhaps an experiment could be conducted to see how using geometry instead of adhesive affects spaceflight. The final thing that the group would change if given the change is the number of people in the group. Since the group was down one person, it put a greater strain on the rest of the members. It is felt that we would be able to be more creative and pursue more complicated experiments if the group was not worried about the workload becoming overwhelming.

- Effort “in” is proportional to rewards out

- If at first you don’t succeed . . . . Cover it with strapping tape.

- Life is like a team . . . You never know what you’re going to get.
  Make an effort to get along with your team mates from the start. You’re both human so you already have something in common.

- Take what you get and turn it into something.

Sometimes you get a bad component or a faulty component or a bad situation, in all these take what you do have and put it to use.

- A little ingenuity goes a long way.

Ingenuity can help you tackle problems that seem to be impossible by conventional means, don’t be afraid to think outside the box or try something unheard of.

12.0 Appendix

12.1 Team Project Documentation Writing Assignments

Team Name Four Guys 1 Box

Introduction	Salman Khan
Mission Overview	Brad Finely
Payload Design	Taylor Garcia
Project Management	All
Project Budgets	Jason Checky
Payload Photographs	Salman Khan
Test Plan and Results	Brad Finely
Expected Science Results	Jason Checky
Launch and Recovery	Taylor Garcia
Results and Analysis	All
Conclusions and Lessons Learned	All

Oral Presentation Assignments

Conceptual Design Review (CDR)	Salman Khan	Taylor Garcia
Flight Readiness Review (FRR)	Jason Checky	Brad Finley

Payload Build Assignments

Overall team lead and ground-testing lead	Taylor Garcia
Flight computer (BalloonSat Easy) build	Taylor Garcia
Weather station build	Jason Checky
Payload box build	Brad Finley
Photographer	Salman Khan
Programmer (of flight computer(s))	Taylor Garcia
Camera and camera experiment	Salman Khan
HOBO (payload "health" (internal temp))	Brad Finley
"Other" science experiment	Jason Checky

Launch Day Assignments

Assign each team member a specific responsibility for launch day. (Rev 0)

Photographer	Salman Khan
Prediction/tracking assistant	Jason Checky
Balloon filling and release assistant	Brad Finley
Payload/stack handling specialist	Taylor Garcia
Recovery specialist (needs to go on chase for sure)	Taylor Garcia

12.2 Flight Computer Code

```
File: FreshmanSeminarFlightCodever3 (used Fall 2010)

symbol record=w0  'This is the section where the variables are declared
symbol index=w1
symbol value=b4

BalloonSat:
  symbol Max_ADC = 2                        ' maximum adc channel usedstarting
with 0
  symbol Mission_Delay = 15000              ' length of pause in mission loop 15
seconds

Mission_Prep:
  i2cslave %10100000,i2cfast,i2cword        ' set memory speed to 400 kHz
  if pin7 = 1 then Download_Data              'and one word records
```

```
flashed:                                        'this section is the section
that waits
high  3                                 'for commit pin to be pulled
pause 1000                                      'the flahser is also in this
section
low 3                                           ' it flashes at a specific rate
pause 1000
if pin7=0 then flashed


Mission:                        ' will change pattern of flashing when data is
being taken

  gosub Analog                                 ' collect analog voltages
  write 0,record                               ' store the number of records
collected
  gosub On_Flash                         ' pause.....

  goto Mission                                 ' ....before starting all over


Analog:
  for index = 0 to Max_ADC                ' loop for number of analog voltages
to record
    readadc index,value                   ' get next adc value
    gosub Record_Data                     ' go store the value
  next                                    ' until last voltage is recorded
  return                                  ' return to main mission loop


Record_Data:
  if record = 3000 then End_Mission     ' check that aren't writing too many
records to memory
  record = record + 1                   ' increment record number
  low 0                                 ' unwrite protect memory
  writei2c record,(value)               ' write the next record to memory
  pause 10                              ' wait 10 ms for write
  high 0                               ' write protect memory
  return                               ' return to the calling calling
subroutine

On_Flash:
       high 3
       pause 1000                               'flash twice than a long pause
       low 3
       pause 500
       high 3
       pause 1000
       low 3
       pause 12500
return


Download_Data:
sertxd ( cr,lf)
sertxd (cr,lf)
sertxd ("Welcome to Balloonsat Easy Data Download Routine ",cr,lf)
```

```
sertxd ("Data Download will be in 3 seperate interface sections",Cr,lf)
sertxd ("After the data section is completed copy input buffer to a text
file",Cr,lf)
sertxd ("Then clear input buffer and replace the commit pin when read back
resumes remove commit pin ",Cr,lf)
Sertxd (" Clear the input buffer and replace the commit pin")

gosub flasher

sertxd ("Data section 1 of 3",Cr,lf)

  for record = 1 to 1000

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,",")                          ' serial out the data
record
         record = record + 1

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,",")                          ' serial out the data
record
         record = record +1

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,Cr,lf)                          ' serial out the data
record
   next
   sertxd ("Data section 1 of 3 Complete",Cr,lf)
gosub flasher

sertxd (Cr,lf)
 sertxd ("Data section 2 of 3 ",Cr,lf)


 for record = 1000 to 2000

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,",")                          ' serial out the data
record
         record = record + 1

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,",")                          ' serial out the data
record
         record = record +1

         readi2c record,(value)                        ' read the recorded
record
         sertxd (#value,Cr,lf)                          ' serial out the data
record

      next
```

```
       sertxd ("Data section 2 of 3 Complete",Cr,lf)
    gosub flasher                                                        ' waits
to replace the commit pin
                                                                         ' than
remove commit pin
sertxd (Cr,lf)
 sertxd ("Data section 3 of 3 ",Cr,lf)

    for record = 1999 to 3000

          readi2c record,(value)                       ' read the recorded
record
          sertxd (#value,",")                         ' serial out the data
record
          record = record + 1

          readi2c record,(value)                       ' read the recorded
record
          sertxd (#value,",")                         ' serial out the data
record
          record = record +1

          readi2c record,(value)                       ' read the recorded
record
          sertxd (#value,Cr,lf)                         ' serial out the data
record

   next
    sertxd ("Data section 3 of 3 Complete",Cr,lf)
 gosub flasher

sertxd (Cr,lf)
sertxd ("Data Download Complete",Cr,lf)                  ' until last data
record read out
gosub LT_down


LT_down:
        high 3                          'flash 3 times than pause
        Pause 1000                              'signifies completed
        low 3                           ' download data
        pause 500
        high 3
        pause 1000
        low 3
        pause 500
        high 3
        pause 1000
        low 3
        pause 10000
   Goto LT_down

    flasher:
        pause 1000
        if pin7=1 then flasher          'waits the for commit pin
        return
```

```
End_Mission:   'this is if data was recorded during the whole flight
        low 3          ' this shows that the memory is full
        pause 10000          ' and that the flight computer functioned
properly for the flight
        high 3
        pause 1000
   goto End_Mission


'this program has a problem
' it writes the record location to internal memory not to the
' 16 bit 1 word memory chip on the balloonsat easy 2.0 flight computer board
'there forethe data should exist for any


  end                                           ' end of mission
```

12.3 Works Cited

The expected scientific results were based off of previous data and information found at the following sources:

Verhage, Paul. *Near Space: Designing Your Own Program of Near-Space Exploration.* Pages 1-12. N.D.
October 14, 2010.
<http://www.aem.umn.edu/courses/aem1905/fall2008/NearSpace0.pdf>

Russell, Randy. *Layers of Earth's Atmosphere.* September 1, 2010. October 14, 2010.
<http://www.windows2universe.org/earth/Atmosphere/layers_activity_print.html>

Mahoney, MJ. *US Standard Atmosphere 1976.* N.D. October 14, 2010.
<http://mtp.jpl.nasa.gov/notes/altitude/StdAtmos1976.html>

Brooks, Cassidy; Huff, Isabel. *The Effect of Altitude on Relative Humidity.* Februray 4, 2006.
October 14, 2010.
<http://www.physics.umt.edu/borealis/RH%20Lab%20Report_06.pdf>