Colorado Space Grant Consortium

DemoSat
Design Document

Cosmic Fury

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May 18, 2013
Revision D
Table of Contents

1.0 Mission Overview 3
   1.1 Goals and Objectives 3

2.0 Requirements Flow Down 3

3.0 Design 4
   3.1 Scoring System 4
   Table 1: Design Evaluation Matrix 4
   3.2 Detailed Description of Final Design 5
   3.3 Components 5
      3.3.1 Altimeter and Pressure Sensor 6
      3.3.2 Relative Humidity Sensor and Temperature Sensor 8
      3.3.3 Circuit Board and Data Storage 9
      3.3.4 Battery Source and Heating Element 12
      3.3.5 Housing and Attachment System 14

4.0 Management 16
   4.1 Schedule 16
   5.0 Budget 16
      Table 2: Cost of Components 17
      Table 3: Mass Budget 18

6.0 Test Plans and Results 18
   6.1 Structural Testing 18
      6.1.1 Whip Test 18
      6.1.2 Drop Test 19
      6.1.3 Stair Pitch Test 19
   6.2 Environmental Testing 20
   6.3 Functional Testing 20

7.0 Expected Results 21

8.0 Launch and Recovery 22

9.0 Results, Analysis, and Conclusions 24
   9.1 Outside Temperature 25
   9.2 Inside Temperature 25
   9.3 Pressure 26
   9.4 Relative Humidity 27

10.0 Ready for Flight 27

11.0 Conclusions and Lessons Learned 28

12.0 Message to Next Year 28

References 29
1.0 Mission Overview
Cosmic Fury has been enthusiastically working on the WeatherSat project that was laid out in the DemoSat-B 2011-2012 User’s Guide received Monday, August 27th. The team understands that DemoSat is a program sponsored by the Colorado Space Grant Consortium in order to provide students with the opportunity to explore the edge of space [1]. DemoSat projects range from bacteria experiments to radiation studies. The purpose of Cosmic Fury’s particular project is to determine weather conditions such as temperature, pressure, and relative humidity in the upper atmosphere. We will do this by designing, fabricating, launching, and recovering a satellite payload that will be attached to a balloon as per the DemoSat guidelines [2].

All DemoSat projects involve concepts, methods, or techniques that could be useful in future space missions. For example, the WeatherSat experimentation could provide potentially useful weather measuring techniques for application in a Mars-like environment.

The team understands that this wider scope of the project implies that our satellite’s payload needs to function within a space-like environment and record data during flight as well as after landing [2]. Therefore, the container of the payload must shield all enclosed equipment from harms including extremely low temperatures, lack of atmosphere, free fall, extreme accelerations, and impact at landing site. Also, according to the DemoSat guidelines, the payload needs to be able to attach, preferably through the center, to the nylon cable that is attached to the balloon [2]. The payload must also comply with the weight restrictions of 1.2kg [2].

1.1 Goals and Objectives
It is the team’s goal to solve this problem and address these needs by following the guidelines to create a satellite that not only measures the required weather conditions, but that also survives the trip.

2.0 Requirements Flow Down
There were many requirements for this project most of which came from the User’s Guide provided by DemoSat. Some requirements are base requirements (Level 0) and other requirements stem from the base requirements (Level 1). Our overall design was driven by all of the requirements.

Level 0:
- Payload mass will not exceed 1.2kg
- Project will remain under budget of $500
- Payload will survive atmospheric conditions
- Payload will function for entirety of the flight

Level 1:
- Flight string will pass through the center of the payload
- Pass-through hole diameter will not exceed 6.4mm and will be free of burrs and sharp edges
- Activation switches will be external/accessible
- Payload size will be minimized with no parts separate from the payload
• Center of gravity will remain as close to the flight string as possible
• Payload will be electrically self-contained
• An adequate thermal system will be provided
• Payload will pass all structural, environmental, and functional testing

3.0 Design
Cosmic Fury investigated several different design options to fulfill the requirements of this project. The team then evaluated these options based on five criteria: cost, mass, size, durability, and range.

3.1 Scoring System
As seen in Table 1, the weights of all of the criteria add up to 100% making the relative importance of each one apparent. Additionally, the raw scores range from 1 to 10, higher being preferred. The optimum score is 1000 points. We performed evaluations for four different categories: relative humidity, temperature, pressure, and data storage. The team chose the best option for each of these categories based on the scoring system, which are highlighted in green.

Table 1: Design Evaluation Matrix

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3.2 Detailed Description of Final Design

Cosmic Fury’s WeatherSat will be equipped with the most cost effective and lightweight sensors with the best possible data collection ranges. These sensors will collect pressure, temperature, and relative humidity data that will be relayed to a circuit board and stored on a MicroSD card. All components will be powered by AA batteries and kept warm by hand warmers. The entire system is housed within a Plexiglass prism shaped housing as well as Ethafoam to shield from all expected near-space conditions (Figure 1). The combination of these components will create an effective, lightweight, and cost effective design for the project.

Figure 1: Satellite Isometric View Sketch

3.3 Components

The key systems of the WeatherSat project include: altimeter and pressure sensor, relative humidity and temperature sensor, circuit board and data storage, battery source and heating element, housing and attachment system.
3.3.1 Altimeter and Pressure Sensor

**Purpose and Function**
Although we will be provided with altitude data for the flight from the control load, the team decided it would be advantageous for us to record our own altitude measurements. For this reason, Cosmic Fury has chosen to include an altimeter on the satellite that will also conveniently measure pressure. Fundamentally, altimeters work by measuring changes in atmospheric pressure in order to calculate changes in altitude [16]. Therefore, this device provides a two-in-one function.

**Technical Specifications**
The team has specifically chosen the Altimeter Module MS5607 manufactured by Parallax, Inc. It is a high-resolution altimeter sensor that includes a built-in linearity barometric pressure sensor as well as a temperature output thus allowing us to measure both pressure and altitude without additional sensors. Suggested applications include rocketry, robotics, weather stations, and ballooning [17]. The Altimeter Module MS5607 is 2.20 cm by 2.03 cm (Figure 2). It is extremely small and lightweight which is particularly beneficial considering the overall weight restriction of 1.2kg [2]. The MS5607 Module is made of a small board with seven input pins including pins for a voltage supply and microcontroller setup [18]. The unit has a power requirement of 3.3 to 6.5 VDC [19]. The altimeter costs $29.99 and was purchased from parallax.com [19]. This is a larger portion of the budget than some other items on the satellite, but well worth the investment. With the capability of measuring two parameters with one device, the altimeter will be very beneficial to our overall design.

**Project Requirements**
The Altimeter Module MS5607 successfully complies with all of the requirements of the WeatherSat project. First, this device has successfully been tested at an altitude of 120,000 feet [19]. This bodes well for us as the DemoSat balloon is only estimated to travel to an altitude of about 100,000 feet [2]. Secondly, the pressure at 100,000 feet is estimated to drop to about 11 mbar according to Wolfram Alpha [20]. This altimeter will successfully measure this pressure as its range goes down to 10 mbar and up to 1200 mbar [19]. Many of the available sensors within our budget do not have the capabilities of measuring pressures this low. In addition, we know that temperatures in the upper atmosphere are expected to drop to -60 degrees Celsius, but that with our heating system, the payload is expected to be kept above 0 degrees Celsius [2]. The altimeter is specified to function between -40 and 85 degrees Celsius and will therefore operate well within the range of the payload itself. The Altimeter Module MS5607 complies with and exceeds the project requirements.
Assembly and Operation
The altimeter will connect to the Arduino as well as a proper voltage supply within 3.3 to 6.5 VDC via the VIN pin (Figure 3). This voltage supply will also be the same supply powering the Arduino and other elements. Once the device is powered on, sample code provided by the manufacturer, Parallax, will be loaded onto the altimeter [17]. Fortunately, no external hardware is needed to operate the MS5607 Module. The altimeter will be surrounded by foam within the housing to ensure its protection during flight and landing. Overall, the altimeter interfaces with the power supply, microcontroller, and the housing.

An altimeter’s operation depends largely on the weather conditions on launch day [16]. Atmospheric pressure varies greatly with changes in weather patterns. If pressure is lower than on a clear day, the altimeter will read higher than it is supposed to and vice versa. These difficulties will only affect altitude readings, not pressure data. Normally, to compensate for these weather changes, an altimeter needs to be calibrated [16]. However, this particular model comes pre-calibrated with calibration tests stored on the sensor itself- another benefit to this particular model [18]. In addition, the manufacturer warns that the unit will not function in a “wet environment” and that direct light will give false readings [18]. The team will heed to these warnings and make the necessary adjustments.
3.3.2 Relative Humidity Sensor and Temperature Sensor

**Purpose and Function**
The temperature probe and relative humidity sensor will interface with the circuit board and will collect the temperature and relative humidity data during the flight.

**Technical Specifications**
The One Wire Sensor was chosen for the temperature probe, as it has the best low-end range of data collection of any of the sensors looked at and can be powered through the data transmission wire [21]. This probe will collect data to -55°C and, although outside of our projected -60°C range, is the most economical option. Data storage is also done in 12 bit words, which makes for easy storage and data retrieval. The Max Detect RHT01 sensor was chosen as the relative humidity, RH, sensor. This sensor is compact and lightweight and includes the necessary programming libraries needed to interface with the circuit board. The power required, 1 milliAmp, is conducive to a longer flight [22]. The data collection range from 20%-90% RH indicates that this sensor will be able to record the anticipated 85% RH during the flight.

**Project Requirements**
The One Wire Sensor was purchased from Sparkfun Electronics and cost $4.25. The Max Detect RHT01 sensor was also purchased from Sparkfun Electronics and cost $9.95. This sensor uses low energy consumption and for the range it can preform at is a good purchase.

**Assembly and Operation**
The housing will contain both the temperature probe (Figure 4) as well as the relative humidity sensor (Figure 5), which will be attached to the circuit board. The data collected will be stored in a shielded microSD, which will be analyzed after flight. All of the aforementioned components are off
the shelf and include set up instructions. Some knowledge of computer programming is required to interface the components with the circuit board and will be successfully completed.

Figure 4: One Wire Temperature Sensor  
Figure 5: Relative Humidity Sensor

3.3.3 Circuit Board and Data Storage

Purpose and Function
The purpose of the circuit board and data storage key system is to be able to interpret, record and store all of the data taken from each of the sensors on board the satellite. This means that the circuit board needs to be connected to each of the sensors through at least two separate wires for data transfers to occur. Furthermore, many of the sensors being used will be powered through the circuit board. This allows for the use of just one battery pack instead of a number of smaller batteries for each of the sensors being used. The circuit board being used is an Arduino R3 (Figure 6), a derivative of the Arduino Uno. A MicroSD Shield will be used to expand the storage capacity from the local 2 megabytes of memory on the circuit board to a full gigabyte of flash storage on a microSD card (Figure 7). The MicroSD shield will be mounted directly on top of the Arduino R3 to minimize space within the satellite (Figure 8).

Technical Specifications
Due to the fact that each of the sensors need to be directly attached to the circuit board, it is wise to place it as centrally as possible within the satellite. Because there will be a nylon cable running through the exact center of the satellite, the circuit board will need to be placed slightly to the side of the cable. This key system will be in direct contact or communication in some form with all of the other key systems apart from the attachment system.

Project Requirements
As per client specifications, this key system will be able to measure and record temperature, pressure and relative humidity throughout the entirety of a weather balloon flight that will reach a maximum altitude of roughly 100,000 feet.

Assembly and Operation
Both the Arduino R3 and the MicroSD Shield are off the shelf parts, meaning that no immediate assembly is required. However, in order to record data, each of the sensors (pressure,
temperature and relative humidity) as well as a power supply in the form of a battery pack will need to be wired to the board. Finally, a short program will need to be written in C++ in order to direct the circuit board how to recover the data from each of the sensors, organize it into a vector array and finally store it correctly on the microSD card for later retrieval after the flight. It is critical that the assembly process is done correctly, as there is risk of losing data, over-volting components or simply failing to take, interpret and store data correctly if the assembly process is done incorrectly.

After the assembly has been completed, this includes both the proper wiring of the sensors and power supply as well as uploading a viable program to the circuit board; the actual operation of the key system is quite simple. Assuming that the program has been written correctly, the device will start taking data as soon as the power switch is flipped. It will continually take and record data for as long as the power switch is on. Once the desired data has been taken, all that needs to be done is to turn the device off, remove the microSD card from the MicroSD Shield and plug the card into a computer to retrieve the data. As mentioned above, the assembly stage is crucial to the success of this key system, however, if the assembly stage is completed correctly, operation of this key system becomes very simple.

Figure 6: Arduino R3
Figure 7: MicroSD Shield

Figure 8: Arduino & MicroSD Shield
3.3.4 Battery Source and Heating Element

**Purpose and Function**
Our WeatherSat satellite’s purpose is to measure and record weather data during flight in the upper atmosphere (around 30km). Temperature at this height can be extremely low, down to around -60 degrees Celsius. The purpose of the heating element is to keep equipment inside the housing above a certain temperature in order for components function properly. Our goal is to keep the inside of the payload around 0.0 degrees Celsius.

Different components of the satellite require a certain amounts of voltage to operate. The Altimeter will require 3.3-6.0V, humidity sensor 3.3-6.0V, one wire digital temperature sensor 3.-5.5V, and the circuit board 5.0-20.0V. The purpose of the battery is to disperse energy to different components inside the payload.

**Technical Specifications**
The hand warmers Cosmic Fury chose align with the size requirements laid out in the DemoSat-B 2011-2012 User’s Guide [2]. In order to allow for proper flight, the size and weight must be small. The dimensions of the hand warmers are 0.130 inches thick, 4.650 inches wide, and 5.990 inches long [23]. The small size allows for the placement of multiple hand warmers.

The AA batteries needed to power components of our payload also fit the requirements of being small in size. AA batteries are 48.5 mm long and 0.4 mm wide (Figure 9). The small size will make it easy to place multiple batters where needed in the payload.
The budget for Cosmic Fury’s WeatherSat cannot exceed $500. Therefore, cost must be kept in mind with every decision made for purchasing components of the payload. The cost of the hand warmers proved to be the most efficient way of providing a heating element. A box of 40 hand warmers cost only $19.89. This will provide more than enough hand warmers for all testing purposes as well as the actual flight. AA batteries are an option that will meet our budget requirements. A value pack of AA batteries will provide enough batteries for testing and the actual flight. A 36 pack costs $14.98, which is only a small dent in our budget.

DemoSat-B 2011-2012 User’s Guide states the payload must comply with a weight restriction of less than 1.5 kg. Therefore, choosing components requires consideration to this weight restriction. The hand warmers weigh only 3.37 grams, which will allow for the use of multiple warmers inside the housing. The power source chosen, AA batteries, also meet the weight requirements laid out by the User’s Guide. Although the batteries will use more of our weight restriction than desired at 11.5 grams, taking into consideration their size and cost, Cosmic Fury is compromising the added weight.

**Figure 9: AA Battery**

### Project Requirements

Cosmic Fury came up with two options that would allow for these requirements to be met. One option was electric heaters that would have one temperature sensor outside the satellite’s housing and one inside. Whenever the temperature sensor on the inside reached below 70 degrees a signal would be sent to the heater to turn it on. Our second option was using hand warmers for temporary heating. Because our satiate will only be in flight for 2.5 hours, hand warmers are more than sufficient as they provide heat for 7 hours. Also, they are very cost effective and come in value packs that would allow for multiple test runs with the hand warmers intact.

One option for a power source is using rechargeable batteries. This would allow for the correct amount of voltage to be sent to the proper components. Also, it would reduce our overall cost.
because we would be able to use the same batteries from testing for our actual flight. Another option to meet these required voltages is AA batteries. Each AA battery produces about 1.5V of power. This will allow for the tailoring of voltage so we can manipulate the batteries to get the amount of power needed for each individual component. This is the method chosen by Cosmic Fury because of the cost efficiency and weight constraints.

Assembly and Operation
In order to keep the inside of the payload around 0.0 degrees Celsius at all times, multiple hand warmers will be adhered around the inside of the housing using double sided sticky tape. This will allow for the distribution of heat to all the components that require being above a certain temperature in order to function properly.

In order to power the payload, multiple AA batteries will be connected through wires to components that require voltage. Barrel Jack Connector battery holders will be used to hold the batteries (Figure 10). The battery holder will be connected to the barrel jack on the Arduino.

Figure 10: Battery Housing

3.3.5 Housing and Attachment System

Purpose and Function
The purpose of the housing unit and attachment system will be to keep the other systems safe during flight and secure them to the balloon. The attachment system will go through the housing unit and keep the payload attached to the balloon throughout the flight.
Technical Specifications
There are a variety of specifications that are relevant to the housing and attachment systems. All of these specifications were taken into account when deciding how to build the unit. The shape of our satellite was dependent on the devices that were purchased. The three shapes that were considered for this project were a cube, a prism, and a cylinder. Our final design utilizes a prism shape. The size of the entire satellite must be kept within a reasonable range. Increased size usually indicates increased mass, so these two criteria are linked. For these reasons, a smaller size is preferred for the housing unit.

When the satellite is in flight, it will encounter some extreme conditions including extreme low temperatures, lack of atmosphere, free fall, and finally impact on landing. Therefore, it is necessary for the housing unit to be durable in order to withstand these conditions. Plexiglass will be used for the outer layer of the housing unit and added Armacell rubber pipe insulation will help protect the payload from any rough bumps or falls (Figure 11). Ethafoam will be used to protect the objects inside of the payload.

Figure 11: Housing and Attachment System

The flight string used for the attachment system will pass through the center of the payload. The flight string will consist of a single 4.0 mm nylon braided cord. The pass-through diameter will not exceed 6.4 mm and will be free of burrs and sharp edges. It was recommended that a center tube be used for the flight string and that the tube be integrated to the payload structure. The tube will be made of plastic [2].

Project Requirements
When used effectively, the housing system will keep all objects safe and in place throughout the flight and landing. The attachment will be effective when it keeps the payload attached to the weather balloon throughout the flight and landing.
**Assembly and Operation**

In order to assemble the attachment system, a hole will need to be cut through the center of the top and bottom of the Plexiglass box. A knot will be tied on each side of the payload and each university may use as much flight string as needed [2].

**4.0 Management**

Cosmic Fury consists of four team members: Chelsea, Scott, Nyana, and Alyse. Each member has a specific role and contributes to the team’s collective efforts. Research, tasks, subsystems and all other work were divided up to assure an efficient and effective team. We all had to rely on each other to complete a successful project. Weekly meetings greatly aided in the management of the team and the project.

![Team Roles Diagram]

**4.1 Schedule**

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**5.0 Budget**

The team was allotted a monetary budget of $500 for this project. The final design has a total cost of $401.33. Table 2 shows how this amount was divided among the different key systems
as well as the items purchased for each system. Our mass budget was limited to 1.2kg or about 42.33 ounces. Our final mass was 41.30 ounces and Table 3 shows how this mass was split between different components and subsystems. The project was finished both under monetary budget and under mass budget.

**Table 2: Cost of Components**

<table>
<thead>
<tr>
<th>Key System</th>
<th>Item</th>
<th>Quantity</th>
<th>Individual Cost</th>
<th>Total Cost</th>
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<tbody>
<tr>
<td>Altimeter &amp; Pressure Sensor</td>
<td>Altimeter Module MS5607</td>
<td>1</td>
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<tr>
<td>Relative Humidity &amp; Temperature Sensor</td>
<td>Humidity and Temperature Sensor-RHT03</td>
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<td>One Wire Digital Temperature Sensor-DS18B20</td>
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<td>Samsung Oem microSD-Programmed</td>
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<td>Arduino Uno-R3</td>
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<td>Battery Source &amp; Heating Element</td>
<td>Energizer AA 36-Pack</td>
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<td>Battery Holder - 4xAA to Barrel Jack Connector</td>
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<td>Hot Hands Handwarmers-10 Pair</td>
<td>3</td>
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<td>Housing &amp; Attachment System</td>
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<td>2 Hole L-bracket</td>
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<td>Armacell Rubber Self- Seal Pipe Wrap Insulation</td>
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<td><strong>Total Overall Cost</strong></td>
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17
6.0 Test Plans and Results

6.1 Structural Testing
For the structural testing, we tested a structure that was similar to the actual structure used for flight. This structure was a prism made from Lexan Plexiglass held together with Loctite glue, silicon, and L-brackets for added stability. Structural tests were performed at room temperature and the flight string was attached through the center of the satellite with knots tied on both ends. This type of testing included three tests: whip, stair pitch, and drop.

6.1.1 Whip Test
The purpose of the whip test was to evaluate if the payload would survive the strong forces that would be felt during free fall. The test was performed by spinning the payload overhead as fast as possible as well as imparting directional changes to the payload by pulling hard on the flight string. The length of the flight string during testing was approximately 2.5 feet. Results of testing showed that the flight string casing stayed securely in place and there was no damage to the test structure.
6.1.2 Drop Test
We performed a drop test to simulate the impact upon landing that the satellite would experience after the flight. For this test, we dropped the payload from a height of about 20 feet onto a concrete landing. It was found that the test structure remained unharmed and the Plexiglass did not crack or break. This was because the added pipe insulation foam cushioned the fall. Additionally, the foam was not damaged during testing.

6.1.3 Stair Pitch Test
The purpose of the stair pitch test, the final structural test, was to simulate the harsh environment that the payload would possibly experience upon landing such as being dragged across a field with rocks and other obstacles. For this test, the team pitched the payload down a flight of eighteen concrete stairs onto a concrete landing. Even after several tests, the payload received minimal damage. The Plexiglass did not shatter and the flight string remained unharmed. Basically, the box bounced down the stairs and was protected due to the padding. Again, the padding was also unharmed.
6.2 Environmental Testing
The environmental testing for the project consisted of a cooler test. The purpose of this test was to ensure that the payload would survive the extreme cold temperatures of the tropopause and that all components inside would be kept at operational temperatures. This test was performed by placing the payload in an environment cooled with dry ice for a period of three hours. After this test, it was found that the inside temperature remained sufficiently high for all components to remain operational as all sensors operate between -40 and 85 degrees Celsius. We also discovered that the hand warmers used were still warm/hot to the touch even after three hours. Immediately after the cooler test, we repeated structural tests to verify that the satellite could pass the structural tests, even at cold temperatures. The team found that even though the Plexiglass was cold, it did not shatter during testing and even though the rubber padding was cold and stiffer, it was still flexible enough the cushion falls and protect the payload.

6.3 Functional Testing
For functional testing, we did a bench test. We left the payload to operate for 2.5 hours to test if all components and sensors would have sufficient battery life to function for the entire flight time. Preliminary tests were successful for both the temperature and pressure sensors, but not for the relative humidity sensor. After some more work and effort, the RH sensor also passed the test. Additionally, the memory card proved to have plenty of storage for all data from all sensors.
7.0 Expected Results
There is lots of existing data regarding weather conditions in the upper atmosphere. Therefore, we had clear results that we were expecting to see form our satellite. First, the temperature and pressure were expected to vary with altitude with the pressure decreasing to about 10mbar and the temperature reaching a minimum of -60 degrees Celsius in the tropopause.
We expected the relative humidity to start around 60%, drop to 0% and then vary depending on temperature and pressure during the flight.

It was expected that we would find our payload in good condition and that we would analyze our data and draw conclusions on how the Earth’s physical environment changes with altitude.

8.0 Launch and Recovery
Launch was scheduled for 7:10 am on Saturday morning April 13, 2013. Team members Alyse and Nyana travelled to Eaton, Colorado to launch the project and another Mines team retrieved our satellite for us.
The balloon reached a height of about 100,000 feet. The flight path is depicted in the images below.

Upon recovery, the payload was found to be in near perfect condition with few nicks and scratches. About six thousand points of data were retrieved from the satellites SD card from the
three different sensors. Along with this, we retrieved several cool pictures from our GoPro that went along for the ride.

9.0 Results, Analysis, and Conclusions
Cosmic Fury had a very successful launch, flight, and recovery. The team’s payload was unharmed and we recovered nearly 6,000 points of data and data was recorded for 3 hours and 18 minutes, which included the full length of the flight.
9.1 Outside Temperature
To measure the outside temperature, we used a One Wire temperature sensor connected to the Arduino and attached to the outside of the payload. We expected temperature to drop to about negative 60 degrees Celsius in the tropopause, and then warm back up in the stratosphere during ascent.

As seen in the figure, which plots outside temperature on the x-axis and time on the y-axis, the outside temperature behaved as expected. The graph follows a trend that illustrates the ascent and descent. The outside temperature reached a minimum of -56.44 degrees Celsius in the tropopause, which was close to the expected -60 degrees. It warmed up in the stratosphere at the peak of the flight (31km) and cooled back down during descent. It is also interesting to see how the descent took less time than the ascent, which of course makes sense as the payload was in free fall.

9.2 Inside Temperature
For measuring inside temperature, we used the temperature sensor that came equipped with the relative humidity sensor. With our heating system, we expected the inside of the payload to remain above about zero degrees Celsius and overall stay sufficiently high for all components to continue operation.
The figure shows that the inside temperature generally stayed above zero degrees Celsius. The sensor was not capable of measuring below zero degrees and there is a small time period in the middle of flight when the temperature dropped below this point. All sensors remained active, though, so the temperature did not drop too low. This drop in temperature occurred in the tropopause, when the outside temperature was at a minimum. Once in the stratosphere, the inside of the payload warmed back up again. All of these trends matched expected results.

9.3 Pressure
To measure the pressure, the team chose the Altimeter Module MS5607. It was expected that the pressure would start out around 100k Pascal and drop to about 1k Pascal at the peak of flight around 31km.

The above figure shows that the pressure began around 85k Pascal. This makes sense because the satellite was launched from an altitude higher than sea level. The graph very clearly shows
the drop in pressure with gain in altitude. The minimum pressure was experience at the peak of the flight and was recorded to be about 6,750 Pascal. This did not drop as low as expected, but the difference from land is very apparent. The pressure very clearly increased during descent as well and the steep slope of the graph illustrates how quickly the satellite was descending.

9.4 Relative Humidity
The MaxDetect RHT03 sensor was used to measure the relative humidity on the flight. On the ground, we expected the relative humidity to begin around 60% then drop to 0% during the flight. The team knew that the max relative humidity experienced by the satellite would be around 85% and that the humidity itself varies depending on temperature and pressure.

During flight, the relative humidity ranged from a low of 3% to a high of about 80% during flight, which closely matched our predictions. As the outside temperature decreased in the tropopause, so did the relative humidity and as the outside temperature increased in the stratosphere, the humidity increased. It is also interesting to note that the humidity began at a lower value than it ended. This observation makes sense because in the morning before launch the payload was at a colder temperature than when it was retrieved later in the day when the outside temperature had warmed up.

10.0 Ready for Flight
Seeing as the payload was not severely harmed and that all data was successfully measured, stored, and retrieved during its first flight, very few things need to be done before the satellite is ready for a second flight. The four AA batteries would need to be replaced with new batteries to
ensure enough power is provided for another flight. A new SD card would need to be used and new hand warmers would need to be activated directly before launch. The pipe insulation on the structure could be replaced with new insulation, but the Plexiglass is still unharmed. Otherwise, all electrical components worked as planned and should be kept as currently assembled.

11.0 Conclusions and Lessons Learned
The DemoSat project taught our team many lessons in data measuring and collecting, but also in things like planning, team management, and sticking to a goal. We began this project approximately seven months ago as a part of a class required for school. We ended this project on our own terms because we wanted to see it through to the end. Honestly, the team ran into several struggles once the project was no longer required for a class- loss of motivation, becoming lax on scheduling and completing assignments, etc. It was difficult to work on a project on top of our already heavy course loads when the project was not ‘required.’ As we got closer and closer to seeing the satellite take shape, however, the project turned into something more than an assignment for school- this was our project and we wanted to see it completed. Most of the extreme hard work fell in the last three weeks before school and our knowledge of electronics increased immensely with the help of knowledgeable teachers and friends. In the end, we pulled the project together and had a very successful launch. Even more successful was the data that we retrieved. Not only did our WeatherSat measure and record data for the entirety of the flight; it measured and recorded accurate data that matched our expected results for all of the parameters we measured. It was great to see the trends in weather through the layers of the atmosphere, but it was even cooler to know we had completed a successful project that reached the edge of space.

Through this project the team learned how to better write reports, run tests, give presentations, and electronically set up three sensors to take data. Cosmic Fury also learned a lot about being a team, staying motivated, and turning a goal into reality.

12.0 Message to Next Year
Cosmic Fury would really like to encourage futureDemoSat teams to stay motivated and determined all throughout the project. Everything is very exciting at the beginning and at the end, but the middle is when everything happens and when it all counts. Tasks can seem very daunting, especially amongst everyday life and coursework. Just remember why you are doing the project and use your resources to accomplish your goal. It is likely you will not know everything you need to complete your project, but this is the point! Reach out to fellow teachers and classmates to gain understanding and learn something along the way- as we did for electronics in our case. Ultimately, it is a really neat experience launching your experiment into space, so stick it out, work towards your goal as a team and you will have success! Good luck!
References


