Colorado Space Grant Consortium

GATEWAY TO SPACE
SPRING 2015
DESIGN DOCUMENT

Team Asteria

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Ian Loefgren, Brandon Cott, and Eleanor Rawlinson

March 2nd 2015
Revision A/B

Revision Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date</th>
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</table>
1.0 Mission Statement and Overview

**Mission Statement**

Project Echo will deploy a Balloon Satellite consisting of systems equipped to gather UV ray data, very low frequency (VLF) radio wave emissions, and other information from the sensors and camera required by the Gateway to Space Request for Proposal; in hopes using new
data to compare to previous records as well as gathering new information for stratospheric observations.

**Mission Overview**

The two experiments that make up Project Echo—the UV experiment and the radio experiment—originated from a split of interest in the team. One half was interested in studying UV and how it changed as the BalloonSat ascended, while the other half was interested in collecting radio emissions from phenomena in space. VLF is a relatively new, non-visual way to observe space. With this unique style of observation, this mission can collect information in a field that has not been heavily explored; it can pick up frequencies that identify aspects of space that cannot be picked up by terrestrial telescopes, such as solar flares and other high energy phenomena. The UV data will be compared with existing data from NOAA ground stations in an attempt to see if there are any variations between Project Echo’s data and existing data. In doing this, the team shall investigate differences between UV rays on the ground versus near space, giving insight into how permeable the atmosphere is to varying wavelengths of UV rays.

**UV Experiment**

The Ultraviolet portion of the electromagnetic spectrum consists of electromagnetic waves of wavelengths 400 nm to 10 nm. The three most applicable ranges are UVa (400 to 315 nm), UVb (315 to 280 nm) and UVc (280 nm - 100 nm).

In the upper stratosphere, UVc strikes O2 molecules and splits them apart, completely absorbing the UVc. The free oxygen atoms then bond with other diatomic oxygen, forming O3, ozone, which subsequently absorbs much of the UVb rays, as seen in Figure 1. Very little UVa is absorbed by the atmosphere.

![Figure 1: Ozone Density Profile for the Northern Hemisphere](image)

Collection of UV data will begin at launch and will continue until recovery. The team will then analyze the data to determine the degree of atmospheric permeability to the three

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different types of UV rays. The analysis of UV data will be two-fold. First, the team will look for changes in UV ray intensity as the BalloonSat ascends, which is expected to increase. Second, using existing data from NOAA networks of ground stations, the team will look for changes in atmospheric permeability over time. They expect a small change that would be indicative of changes in stratospheric ozone levels.

Radio Experiment

The radio portion of the electromagnetic spectrum consists of waves from 3 Hz to 300 GHz. Within the range there are named subdivisions, one of which is VLF, or Very Low Frequency. VLF is made up of frequencies of 3 to 30 kHz and is the frequency of many naturally produced radio waves. Celestial bodies with changing magnetic fields, including the Sun and planets in the solar system, produce VLF radio waves.

Radio waves from these phenomena will be collected by the two antennae at the top of the BalloonSat. Once the data is recovered, the team will be able to compare it to data collected on the ground, as well as other existing data sets, with the goal of finding differences between VLF reception on the ground and at 80 km into the atmosphere.

2.0 Requirements Flow Down

Below are the requirements Project Echo must meet in order to be considered a successful mission. Level 0 requirements are mission objectives derived from the Mission Statement. Each requirement is specified by its identifier, to be referenced by higher level requirements, the requirement itself, and what the requirement derives it from.

Level 0 Requirements

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<th>Requirement</th>
<th>Description</th>
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<td>0.1</td>
<td>The BalloonSat shall satisfy all requirements of the RFP.</td>
<td>MS</td>
</tr>
<tr>
<td>0.2</td>
<td>The BalloonSat shall record UV data from onboard UV sensors.</td>
<td>MS</td>
</tr>
<tr>
<td>0.3</td>
<td>The BalloonSat shall record VLF data from the onboard antenna.</td>
<td>MS</td>
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<tr>
<td>0.4</td>
<td>After retrieval, data collected from onboard flight sensors shall be analyzed.</td>
<td>MS</td>
</tr>
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</table>

3.0 Design Details

3.1 Exterior Structure

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The BalloonSat structure shall be constructed out of foam core and sealed with hot glue and aluminum tape to optimize structural integrity of the structure while keeping the system lightweight and well insulated.

The BalloonSat shall be a rectangular cube with exterior dimensions 20cmx18cmx13cm, as shown in Figure 2 below. This size was chosen to maximize wall space where the interior components will be mounted. By placing batteries, Arduinos, sensors, and the circuit board on the inside wall of the BalloonSat, it will keep the components close together to ensure even heating. Components of the BalloonSat are sensitive to temperature extremes, especially the UV sensors which are inoperable below -20°C.

![Figure 2: Exterior Structural Design](image)

The exterior structure shall be constructed out of foam core, of which 3 sheets will be provided by CoSGC. Foam core was chosen because it is lightweight but sturdy, which results in a strong BalloonSat structure without occupying a lot of the 1000g mass limit required by the RFP. A foldable box with the aforementioned dimensions will be cut out of one sheet of foam core with an Exacto knife and folded into the shape of a rectangular cube. Two extra sheets are available in the case of the anticipated structural damage from testing. The BalloonSat shall be reinforced and sealed with hot glue and aluminum tape along the exterior edges. The top will remain open until insulation, the two Arduinos, the antenna circuit, and the digital camera are installed, after which the top shall be sealed with hot glue and aluminum tape in the same manner as the rest of the edges. An 18cmx13cm side will remain unsealed until just before launch to allow for access to interior components. Before launch, this side will too be sealed with aluminum tape.

Through the middle of the BalloonSat, entering through the top and exiting through the bottom, shall be a plastic tube through which the flight-line will pass through, as can be seen in Figure 2, linking the BalloonSat to the weather balloon. The plastic tube is provided by CoSGC and is necessary so that the flight-line does not pull through the BalloonSat. Using a washer and paperclip, the plastic tube shall be secured to the structure of the BalloonSat as described in the RFP.
On the side of the box will be contact information in the case that the BalloonSat is not recovered by the team. Should someone else find it, the team will be contacted.

As stated in the RFP, the BalloonSat shall also have a 6cmx5cm door on the side (see Figure 2) able to swing open for access to switches that activate the humidity, temperature, pressure sensors, and accelerometer. This door will allow access to switches that turn on the systems prior to launch, but will cover the opening in order to maintain a steady interior temperature of above -10°C. Before launch, this door will be sealed with aluminum tape to keep it closed and to further insulate the BalloonSat.

In the center of each of the 4 sides of the BalloonSat (front, back, left and right as shown in Figure 2) shall be holes cut 1cm in diameter through which 4 UV sensors will be exposed to the exterior of the box. These UV sensors are not operable below -20°C so in order to prevent them from malfunctioning in the -80°C environment, a 2cmx2cm piece of 9 thick polyethylene plastic will be glued over the hole between the foam core and insulation in the wall of the BalloonSat. Polyethylene plastic was chosen because it is permeable to UV rays yet a good insulator. The UV sensors will not be pressed up against the polyethylene, but rather sit facing the window. In this way, the sensors will be protected from the harsh cold outside the BalloonSat but still collect UV ray data during the flight. As with most plastics that are insulators, there is a significant amount of light scattering. Because the sensor sits in a 1.5cm deep hole in the side of the box, it is not expected that the scattering will interfere with data collection since the area of the sensor is sufficiently small and focused by the thickness of the foam core walls.

On the top of the BalloonSat will be two antennae, constructed out of a 5cmx5cm copper plate attached to a copper pipe. The copper pipe will be placed under the top of the BalloonSat and secured with electrical tape. The antennae are placed flat on top of the BalloonSat structure, which provides more structural stability than having them stick straight up through the top of the satellite. The orientation of the antennae will not affect collected data in any way.

3.2 Interior Structure

In order to meet the RFP requirement that the interior of the BalloonSat must remain above -10°C, the interior will be lined with 1cm thick insulating material provided by CoSGC. This material will reduce the interior dimensions to 18cmx16cmx11cm. The interior components are organized as shown in Figure 3 below, with most components along the wall in order to maximize heating efficiency.
The heater will be placed on the floor of the BalloonSat towards the middle next to the flight-line as shown in Figure 3. This is to ensure even heating of the interior components, especially the temperature sensitive batteries and UV sensors, which will be mounted on the walls of the BalloonSat.

The thermal system includes the heater kit, consisting of a heater, 3-9V batteries for power, a switch, and an LED indicator. This system is an important component for maintaining an internal temperature above -10°C. The heater was built with 3-4 ohm resistors soldered in series on a perf board. The series of resistors is connected to 3-9V batteries, a switch, and an LED light as shown in the diagram in Figure 4. Before launch, the subsystem will be turned on using the switch, accessible from the opening door on the side of the BalloonSat. The LED, protruding through the wall of the structure and visible on the outside of the BalloonSat, will serve to indicate that the subsystem is running after the BalloonSat is sealed before launch.
The camera subsystem, provided entirely by CoSGC, consists of one Canon digital camera preprogrammed to capture an image every 20 seconds, a 4G SD card, and one lithium-ion battery connected as shown in Figure 5. This subsystem will be secured against the back wall with velcro, the lens of the camera protruding through a hole of 1 cm radius cut in the side of the BalloonSat. The camera will need to be turned on before the BalloonSat is sealed during pre-launch.

The RFP requires that every BalloonSat fly two temperature sensors (one internal and one external), a humidity sensor, a pressure sensor, and an accelerometer. These components are attached to what has been named the Core Arduino. This Arduino is dedicated to managing the collection of environmental data. The Core Arduino is powered by 2-9V batteries and contains a
switch and an LED indicator, as shown in Figure 6. As in the thermal subsystem, the switch allows for the Core subsystem to be switched on and off by access to the door in the side of the box, which will be sealed before launch. The LED indicator will show that the subsystem is operating after the BalloonSat has been sealed. All sensors except the external temperature sensor are soldered directly to the Core Arduino. The external temperature sensor is connected to the Core Arduino with a wire to allow it to extend at least 2.54 cm past the wall of the BalloonSat as required by the RFP. The Core Arduino is connected to a 2G SD card which will collect all the data from the 5 sensors.

![Science Subsystem Functional Block Diagram](image)

Figure 7: Science Subsystem Functional Block Diagram

The second Arduino, dubbed the Science Arduino, is dedicated to collecting data from the 4 UV sensors and the 2 antennae. The UV sensors are connected to the Arduino with wires to allow them to be positioned in one of the 4 sides of the BalloonSat. In order for the Science Arduino to collect meaningful data from the antennae, there are several more components linking the Science Arduino to the antennae as shown in Figure 7. The antennae are both connected to a circuit dubbed the Antenna Circuit (displayed in Figure 8 below), which connects the antennae to the amplifier. This amplifier connects through the Antenna Circuit to a 3.5mm Input jack which is connected to an analog input on the Science Arduino, and converted to an analyzable format by the Arduino. The Science Arduino is powered by 2-9V batteries as the Core Arduino is, however, the circuit for the antenna is separately powered by 1-9V battery so that it does not rely on the Arduino to deliver its minimum requirement of 5.5V. If the Arduino malfunctioned and it’s output voltage dipped below 5.5V, it would impair the Science Arduino’s ability to collect data. A much larger SD card, one of 8GB, was selected for the Science Arduino because the size of the data collected by the antennae will be equivalent to low bit-rate mono audio.
3.3 Sensors

Humidity Sensor:

The humidity sensor, provided by CoSGC, shall be used to measure levels of humidity inside the BalloonSat. It is soldered directly onto the Core Arduino. In the case that interior components malfunction, data gathered by the humidity sensor can determine whether or not the malfunction was due to the high humidity within the BalloonSat caused by a point of leakage in the structure. Raw data is collected as a voltage, then converted into a percentage through a code uploaded onto the Arduino.

Pressure Sensor:

Provided by CoSGC, the pressure sensor gathers data on the air pressure in the environment. The BalloonSat structure will not be airtight, and thus the air pressure within the structure will be the same as outside, allowing the pressure sensor to gather accurate data about the environment from inside the BalloonSat where it is soldered directly onto the Core Arduino. This altitude data is important for mapping the path of the BalloonSat, identifying where it rises, remains steady, and begins to drop after burst. Raw data is collected as voltage, and code for the Arduino converts the data into units of psi.

Accelerometer:

The accelerometer is provided by CoSGC and will be used to collect ascent and descent rates of the flight-line as required by the RFP. It is soldered directly onto the Core Arduino. Raw data is collected as a voltage, which through code written for the Arduino is converted into Gs.

Temperature Sensors:

One temperature sensor will remain in the BalloonSat, soldered directly onto the Core Arduino. The internal temperature sensor will collect data about the temperature of the inside of the BalloonSat, which is important for failure analysis should interior components fail as well as for ensuring that the RFP requirement of maintaining an internal temperature above -10°C is met. The exterior sensor shall be connected to the Arduino along a wire to allow it to be positioned at least 2.54cm outside of the BalloonSat as required by the RFP. This ensures that heat from the interior of the BalloonSat does not interfere with temperature readings from the exterior sensor.

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4 Homebrew E-Field Antenna. http://dl1dbc.net/SAQ/homebrew_e-field.html
environment. Both of these sensors are provided by CoSGC. They collect raw data as a voltage, which is then converted into degrees Celsius.

**UV Sensors:**

6 UV sensors were ordered from banggood.com. Only 4 of these sensors will be used in flight, however 2 extras were purchased in the event of malfunction or damage. The sensors are capable of detecting between 200nm and 370nm wavelengths and require between 3V and 5V to operate. These sensors shall be connected to the Science Arduino along a wire to allow them to be positioned in the center of each of 4 faces of the BalloonSat, the front, back, left and right faces. The sensors function between -20°C and 85°C. When UV rays strike the UV sensors, they output a voltage that changes based on UV intensity. This output is connected to an analog pin on the science Arduino, which will be programmed with an equation developed during the testing of the sensors to convert the voltage measurements to irradiance measured in watts per square meter.

**Antenna Subsystem:**

To collect VLF data, Project Echo will include a custom-made active E-field antenna. This type of antenna was chosen because it allows for the more compact design this project necessitates. This is accomplished by utilizing an amplifier and a copper plate to serve as the antenna. The antenna itself is a flat 5cmx5cm copper plate, attached to a copper pipe, which is then soldered to a wire. This connects to the following circuit, which connects this antenna to the amplifier (TL071P), and the output 3.5mm audio jack. The antenna are characterized and tuned to collect VLF from their connection to the custom circuit (see Figure 8 above) and the amplifier.

**3.4 CONOPS**

The functions of the BalloonSat are mapped as shown below in Figure 9, from startup of systems to shut-down. During pre-launch, the team will focus on assembling and testing the interior and exterior structures. At launch, all subsystems will be turned on from the switches accessible by the door in the side of the BalloonSat and the camera turned on manually before the final side and the switch door are sealed with aluminum tape. While the BalloonSat is rising, all environmental and science sensors shall be on and collecting data. After the burst when the BalloonSat drops, it will be recovered using a GPS tracker attached to the flightline. When it is recovered, the seals shall be broken and all subsystems turned off. To access the data collected by the Arduinos for analysis, the information on the SD cards shall be uploaded onto each team members’ computers.
4.0 Management

In Order to optimize time and resources, team Asteria will meet at least twice a week on Monday and Wednesday in the ITL from 5:00-7:00 pm. Each member will be responsible for attending both, either physically or virtually, and will contact Eleanor if they will not be able to attend. Component testing will be conducted outside of meeting times if not able to be completed within meeting time. Meetings may run late if tasks have not been completed.

4.1 Organizational Chart
The Project leader is Eleanor; her role consists of scheduling meetings and ensuring that the team stays on track for completing the project successfully. Subsystems and their assigned team members are shown below. Each subsystem is led by one team member with a partner to provide backup in the event that the main team member cannot fulfill their responsibilities at some time. The team member in charge of a subsystem will be in charge of determining what needs to be completed for each system, laying a framework for the rest of the team to follow. The subsystems are guided by one member and fulfilled by the team.

### 4.2 Schedule

<table>
<thead>
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<th>Task</th>
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<tbody>
<tr>
<td>Wed. Feb 4</td>
<td><strong>TM</strong> Arduino(HW 04) and Proposal Work</td>
</tr>
<tr>
<td>Thur. Feb 5</td>
<td>HW 04 Due</td>
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<tr>
<td>Sun. Feb 8</td>
<td><strong>TM</strong> Proposal Work and <strong>Spark fun</strong> Work(HW 05)</td>
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<tr>
<td>Mon. Feb 9</td>
<td>Proposal Due-8:00 AM</td>
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<tr>
<td>Tue. Feb 10</td>
<td>HW 05 Due</td>
</tr>
<tr>
<td>Wed. Feb 11</td>
<td><strong>TM</strong> Work On Parts Order (HW 06)</td>
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<tr>
<td>Fri. Feb 13</td>
<td>HW 06 Due -Authority To Proceed</td>
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<tr>
<td>Sun. Feb 15</td>
<td><strong>TM</strong> HW 07 and 08 work</td>
</tr>
<tr>
<td>Wed. Feb 18</td>
<td><strong>TM</strong> Finish HW 07 and 08</td>
</tr>
<tr>
<td>Thur. Feb 19</td>
<td>HW 07 and HW 08 Due</td>
</tr>
<tr>
<td>Sun. Feb 22</td>
<td><strong>TM</strong> Acquire Hardware</td>
</tr>
<tr>
<td>Wed. Feb 25</td>
<td><strong>TM</strong> Begin Preliminary Design Presentation, Cut Prototype Satellite</td>
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<tr>
<td>Mon. Mar 2</td>
<td><strong>TM</strong> Finalize PDR, Finalize Design Document A/B, Fit Hardware</td>
</tr>
<tr>
<td>Tue. Mar 3</td>
<td>Preliminary Design Presentation Due - 7:00 AM</td>
</tr>
<tr>
<td>Wed. Mar 4</td>
<td><strong>TM</strong> Finish Structure And DD A/B, Stair Test</td>
</tr>
<tr>
<td>Mon. Mar 9</td>
<td><strong>TM</strong> Finish Up Structure And Drop Test, Begin Building Radio</td>
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<tr>
<td>Wed. Mar 11</td>
<td><strong>TM</strong> Thermal (Cold) Test, Camera Test, Finish Radio</td>
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<tr>
<td>Thur. Mar 12</td>
<td>Mid Semester Team Evaluations Due</td>
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<tr>
<td>Mon. Mar 16</td>
<td><strong>TM</strong> Satellite Integration Complete, Whip Test And Retests(If Necessary)</td>
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<tr>
<td>Mar 21-29</td>
<td>Spring Break</td>
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5.0 Budget

Joseph will be in charge of managing the budget. This includes making sure that all items are purchased, managing reimbursements with Chris, and that the team does not exceed provided funds. Below is a table with all the items that will be a part of Team Asteria’s Project Echo. As can be seen, the team has not exceed its weight or financial limits.

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<td>957 g</td>
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</table>

* These items have not yet been received, and thus have not been weighed.

5.1 Company Information

- Banggood
  
  www.banggood.com
  
  [0852) 35903678]

- Texas Instruments
  
  www.ti.com
  
  Phone Number: (972) 995-2011
  
  Address:
  
  P.O. Box 660199
  
  Dallas, TX 75266-0199

- Home Depot
  
  www.homedepot.com
  
  Phone Number: (303) 449-4221
  
  Address:
  
  1600 29th Street
  
  Boulder, CO 80301

- Radio Shack
  
  www.radioshack.com
  
  Phone Number: (303) 449-0635
  
  Address:
  
  1895 28th Street
  
  Boulder, CO 80301

6.0 Test Plan
6.1 Structural Testing:

Drop Test:
The Drop Test looks to see if the structure will survive the high-impact fall at landing. The test will consist of placing weights that are equivalent to that of satellite hardware inside the structure and dropping it from a height of ten meters. The test will be considered a success if the exterior structure is able to remain intact after the drop.

Stair Test:
The Stair Test involves dropping the satellite, along with weight equivalents of all satellite hardware, down an empty flight of stairs. This measures structure strength and recreates a BalloonSat landing in windy conditions. The test will be considered a success if the exterior structure is able to remain intact after the drop.

Whip Test:
The Whip Test is essential for testing the structure’s strength during ascent and descent. The satellite will be swung over the head of a team member. This ensures that the structure will not collapse inward due to heavy winds and air resistance as it is in flight. Whip testing will stimulate the intensity of the flight and thus will be performed in an open area. The test will be considered a success if the exterior structure is able to remain intact after the test.

Thermal Test:
During the mission the satellite will reach an altitude of 30 kilometers and will be exposed to cold temperatures up to -80 degrees Celsius. To ensure sufficient insulation, Echo will simulate two in-flight missions by placing the satellite in a cooler of dry ice. The first test will be conducted with only the heater kit and internal temperature sensor operating. The second test will be conducted with all functions of the satellite operating. The first test will be considered a success if the interior temperature remains above -10 degrees Celsius. The second test will be considered a success if all the functions remain operational after the test.

Camera Test:
Echo will also test the function of the camera while the Thermal Test is taking place. To ensure that the camera is in functional condition, the camera will take pictures every twenty seconds. The test will be considered a success if the camera remains operational after the test.

6.2 Sensor Testing:

UV Sensors:
In order to test the four UV sensors being flown, the team will utilize a machine to generate UV rays, found in LASP. This is in order to first make sure our sensors are working properly throughout the UV spectrum. The operating wavelength range for the sensors is 370-200 nm, which, includes UVa, UVb, and (dips into) UVC. The UV sensors only measure...
intensity of UV rays, and cannot differentiate between the different types, so the second objective of testing will be to create a baseline.

The first phase of testing will take place in the UVa range, and will make sure all sensors are giving data, and that the data from each sensor is the same. The second phase will be the same as the first, only using UVb. The last phase will be to determine if the sensors are all sensitive to UVc.

**Radio Telescope:**
The radio telescope system will undergo two different tests. First, it will be tested using a transmitter capable of transmitting radio waves in the 3-30 kHz range and making sure the telescope picks them up. The team will have the transmitter cycle through all the frequencies in this range to make sure the telescope can detect all of them, instead of only some. With this test, the team will also be able to determine if the telescope can detect some frequencies better than others, as this will need to be factored in during data collection and data analysis.

The system will also be tested by using it to collect radio waves from the ground. This will not only confirm the system is working properly, but it will also give the team sample data from natural phenomena which can be analyzed and used for comparison.

**Accelerometer:**
The accelerometer shall be tested by orienting the sensor along the x and z axes. Oriented in each of these directions, the sensor should read 1g for each. It is likely the sensor will not read exactly 1g, and instead slightly less or more. With these tests it is possible to determine the offset necessary to correctly record and calculate accelerometer data. The orientation tests will be run three times in each orientation, x and z, to ensure the difference between actual readings and 1g is consistent.

**Humidity Sensor:**
The humidity sensor will be tested by a team member breathing on it. The resultant data will be processed by the Arduino using an equation to give data in terms of relative humidity.

**Pressure Sensor:**
The pressure sensor will be tested by collecting pressure readings with it in a normal ground environment and comparing these readings to what the team calculates pressure should be at present altitude, and to data from trusted sources. Discrepancies will be recorded.

**External and Internal Temperature Sensors:**
The internal and external temperature sensors will be tested by comparing temperature readings to a trusted thermometer. If there are consistent discrepancies, these can be recorded and factored into calculations in order to collect correct data.

**6.3 Full System Testing:**
After all components of the satellite have been finalized, the team will perform a full system test. During this test, the team will turn on every function for at least 3 hours to ensure that all components of the satellite are working properly. The test will be considered a success if...
all functions remain operational and record data correctly throughout the entire duration of the test. The team will not proceed until this test is successful.

6.4 Safety:

In order to maintain compliance with all safety requirements, Echo will approach all tasks with the appropriate level of caution. All tests will be conducted in safe environments, away from breakable objects (i.e. windows, fragile furniture etc.) and bystanders. All team members will wear appropriate safety gear, and will conduct hazards tests with at least one additional team member present. All tasks will be assigned based on skill; if no team member has the skill required, a team member will receive training on the matter before proceeding.

7.0 Expected Results

The antennae will take in radio waves and record the data to the SD card. This data will be put into the program Audacity, converting it to a spectrogram. A spectrogram shows time on the x-axis and frequency on the y-axis. The intensity of the frequency is indicated by a coloring scale. The results of the spectrograms will be compared to previous data from NASA to identify the phenomena observed. It is expected that solar flares will be observed. An example spectrogram is shown below in Figure 10.

![Figure 10: Expected VLF Data](image)

The UV sensors will record data to show the relationship between altitude and the different forms of UV rays. The team expects that UVA will remain nearly constant while UVB will increase directly with an increase in elevation. UVC is not expected to be observed at all because the BalloonSat will not reach a sufficiently high altitude. The expected relative intensities of the different forms of UV rays with respect to altitude are shown in Figure 11 on the next page.

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5 “Exploring Audacity’s Spectrogram View” – youtube.com
The team expects external temperature to decrease steadily as the BalloonSat rises through the Troposphere. Once the balloon reaches 10 km, it will enter the Stratosphere. As the balloon increases through this layer, it is expected that the temperature will increase. The balloon will burst at 30 km and the temperature will initially decrease then increase as the BalloonSat falls through these layers again. Figure 12 below shows literature values for temperature in relation to elevation. The internal temperature is expected to remain above -10°C throughout the duration of the flight. Example internal temperature data is shown below in Figure 13.
It is expected that as the balloon increases in elevation, the pressure sensor will read a decrease in the pressure. The pressure in the atmosphere decreases exponentially and will approach zero at max altitude. The humidity is also expected to decrease with elevation. Expected pressure and humidity data with respect to elevation is shown below in Figures 14 and 15, respectively.

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8 “Introduction to the Atmosphere: Atmospheric Pressure” http://www.physicalgeography.net/fundamentals/7d.html
The accelerometer is expected to register relatively stable motion during the balloon’s ascend. After burst, the changes in acceleration are expected to change rapidly. Figures 16 and 17 show example accelerometer data in the X and Z directions, respectively.

The camera is programmed to take pictures every 20 seconds. The data from all sensors will be recorded on the SD cards on the Arduino Unos.

http://www.societyofrobots.com/space_balloon_humidity_test.shtml
http://www.physicalgeography.net/fundamentals/7d.html
http://www.seungjoo.net/projects/may2006/

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