Colorado Space Grant Consortium

GATEWAY TO SPACE
SPRING 2017
DESIGN DOCUMENT

Team Panic! at the Cantina

Written by:
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Will Applegate, Matthew Ryan

3/7/17
Revision A/B
## Revision Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date Due</th>
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<tr>
<td>A/B</td>
<td>Conceptual and Preliminary Design Review</td>
<td>3/7/17</td>
</tr>
<tr>
<td>C</td>
<td>Critical Design Review</td>
<td>4/6/17</td>
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<td>Final Draft: 5/10/17</td>
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1.0 Overview and Mission Statement

1.1 Mission Statement

Project Unidentified Flying Sound (UFS) shall be a high altitude BalloonSat, built by Team Panic! at the Cantina for the ASEN 1400 course. UFS shall be sent to approximately 30,000 meters in altitude using a hydrogen weather balloon. UFS’s primary mission shall be to calculate the speed of sound using an ultrasonic sensor throughout its entire flight time and compare that data with varying altitude, temperature, humidity, and pressure measurements to determine the extent to which the speed of sound changes from the launch point in Windsor, Colorado (elevation 1,462 meters above sea level) to near space.

1.2 Mission Overview

Project UFS’s goal is to observe the extent to which the speed of sound changes with varying altitude, temperature, humidity, and pressure levels during its nearly 2 hour and 15-minute flight into near space. By analyzing the data collected by the BalloonSat, team Panic! at the Cantina hopes to develop further knowledge about how the speed of sound is affected by these factors as altitude increases throughout the flight. This topic interests team Panic! at the Cantina due to NASA’s 21 year, 3.27 billion dollar Cassini mission that set off to explore Saturn.1 A main component of the Cassini Mission was the successful landing of the Huygens Probe on the surface of Saturn’s largest moon, Titan, on January 14, 2005.2 The Huygens Probe was equipped with the Surface Science Package (SSP) which included the Acoustic Properties Instrument-Velocimeter (API-V), an ultrasonic sensor used to calculate the speed of sound. Analysis of the sensor data allowed NASA to determine the methane content of Titan’s atmosphere at various altitudes during its descent.3 While project UFS will not be using an ultrasonic sensor to determine atmospheric composition like the Huygens Probe did, its sole purpose is to calculate the speed of sound throughout the flight in Earth’s atmosphere.

The ultrasonic sensor does not actually measure the speed of sound itself but instead calculates the distance from an object assuming the speed of sound at sea level (which is about 340 m/s). The sensor functions by sending out a high-frequency sound ping and then timing how

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long it takes for the echo of the sound to reflect to the receiver on the sensor, like in Figure 2.

![Diagram of ultrasonic sensor functioning](image)

The sensor then uses the equation $\text{Distance} = \text{Speed}_{SL} \times \frac{\text{Time}}{2}$ (where $\text{Speed}_{SL}$ is the speed of sound at sea level) to calculate the distance from a reflective surface with the time measured to receive the echo back, like in Figure 3. The time measured and used in the above equation is divided by two to account for the sound pulse traveling to the surface and back since the calculated distance is only between the sensor and the surface. However, this is not how Panic! at the Cantina intends to utilize the ultrasonic sensor. By fixing the sensor a predetermined distance away from a reflective surface, such as one of the foam core walls of the BalloonSat, the distance is made constant, which will be denoted as "$\text{Distance}_{Box}$" for the distance across the "box" that the ultrasonic sensor will be housed in within the BalloonSat. If the speed of sound changes as project UFS increases in altitude, then the ultrasonic sensor will measure different time values for the sound pulse to reflect off the surface and echo back. Panic! at the Cantina’s second Arduino Uno will be programmed to calculate the speed of sound using the measured time values from the sensor. First it will compute the time values measured by the ultrasonic sensor using a modified form of the above equation, $\text{Time} = \frac{\text{Distance} \times 2}{\text{Speed}_{SL}}$. Then, modifying the equation again, such that speed is variable and distance is a constant, $\text{Speed} = \frac{\text{Distance}_{Box} \times 2}{\text{Time}}$, the Arduino will calculate the speed of sound.

![Secondary Visual of how ultrasonic sensor functions](image)

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1.3 Hypothesis

Team Panic! at the Cantina will be testing how the factors of humidity, altitude, pressure, and temperature affect the speed of sound. It is predicted that the speed of sound will be directly proportional to these factors at different altitudes 

![Figure 4](image-url)

Additionally, Panic! at the Cantina predicts that the temperature will have a stronger correlation factor with the speed of sound than the other tested data. The Dry-Ice Test will be used to gain understanding of how the speed of sound might change with temperature before sending Project UFS into near space.

2.0 Requirements Flow Down

The Requirements Flow Down chart below consists of the level zero requirements set by Panic! at the Cantina for Project UFS. The level zero requirements are derived from the mission statement in Section 1.1.

### 2.1 Level 0 Requirements

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<th>Origin</th>
</tr>
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<tbody>
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<td>0.1</td>
<td>The BalloonSat shall be sent to an altitude of 30 kilometers.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.2</td>
<td>The BalloonSat shall record environmental data throughout the duration of the flight.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.3</td>
<td>The BalloonSat shall record distance values from the ultrasonic sensor throughout the duration of the flight.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.4</td>
<td>The BalloonSat and all data collected in-flight shall be successfully recovered after landing.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.5</td>
<td>All requirements in the Spring 2017 Request for Proposal shall be adequately fulfilled.</td>
<td>Mission Statement</td>
</tr>
</tbody>
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![Anahid Blaisdell 3/10/2017 9:37 PM](image-url)

Comment [8]: Choose one or the other, but please don't choose both.

Comment [9]: Again, don't put the cite on the same thing twice.

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3.0 Design

3.1 Design Overview

Team Panic! at the Cantina will create an optimal structure that will carry our BalloonSat payload and resist the harsh atmospheric conditions experienced during flight. It is essential that our structure will be able to accommodate all the subsystems required for flight and provide seamless integration between the subsystems.

3.2 Structure

For Project UFS, Panic! at the Cantina has designed a 25cm by 20cm by 14cm rectangular foam core box, giving internal dimensions of 24cm by 19cm by 13cm, as seen in Figure 5. These dimensions were chosen for simplicity of wiring and assembly as well as ease of access for pre-flight modification and post-flight data recovery. Also, foam core shall be used as the external structure due to the high strength to weight ratio that it offers. The external foam core walls of the BalloonSat shall have a sticker of an American Flag on the outside as well as Panic! at the Cantina’s contact information in order to increase the retrieval success rate of project UFS after landing. Lastly, all designs and documentation shall consistently use metric units for simplicity and clarity.

![Figure 5 - Dimensions of overall structure of BalloonSat](image-url)
LEDs protrude from three sides of the box, indicating power status of the three inside circuits. On one of these sides a temperature sensor sits to measure the temperature outside of the box. A 3.6cm by 3.6cm rounded square will be cut out of the fourth side as a viewing hole for a GoPro Hero4 Session. On the top, a humidity sensor will collect moisture data from the atmosphere. Passing through the center of the box (from top to bottom) will be a non-metal tube 1.5cm in diameter, with an inner diameter of 0.5cm for the flight string to fit through. This tube shall be attached in such a way that it will not interfere with the flight string. All of which can be clearly seen in Figure 6 below.

Figure 6 - 3D rendering of BalloonSat with labeled parts
The inside structure consists of two main compartments. The larger compartment is lined with 1.5cm foam insulation, limiting inside working space to approximately a 21cm by 16cm by 10cm rectangular prism. This compartment will hold all the temperature-sensitive equipment such as the Arduinos, GoPro, and many of the sensors. A heater will sit at one end of the compartment, combating the outside cold while an inside temperature sensor will measure temperature inside of the box. It is from this compartment that pressure, acceleration, and visual data will be taken. The large compartment will also store the two microSD data storage chips and the five 9V battery power supply.

\[ 
\begin{array}{c}
\text{Figure 7 - Dimensions of Sound Chamber}
\end{array} \]

The smaller second inner compartment of the design is 6.5cm by 8.5cm by 14cm on the outside, contained on four sides by an outside edge of the box, as depicted in Figure 7. This compartment contains no foam insulation, giving it inner dimensions of 6cm by 8cm by 13cm. A temperature sensor sits inside, measuring the temperature within this compartment. Centered on the 6cm wall of the compartment, an ultrasonic sensor will poke through the foam core walls. This design will allow the ultrasonic sensor to operate within the box while providing some thermal protection for the temperature-sensitive chip. With almost 8cm between the sensor and the far wall, the ultrasonic sensor will have distance sufficiently greater than the minimum needed to record data, which is around 2cm. On the top and bottom of the compartment will be three circular vents, all 1cm in diameter, to allow the atmosphere to flow through and provide a medium as close as possible to the outside of the box, which can be seen in Figure 8 below. This will be the compartment where our speed of sound experiment will take place and for that reason will be henceforth referred to as “the sound chamber.”
3.3 Subsystem Design

3.3.1 Scientific Instruments/Experimental Design

Project UFS will be flying the standard scientific sensors that are a part of the Gateway to Space class requirements. The required scientific sensors include an accelerometer, a pressure sensor, a humidity sensor and two temperature sensors. In addition to these sensors, project UFS will be using an ultrasonic sensor to measure the speed of sound and an extra internal temperature sensor located in the sound chamber to record accurate data of the temperature in this specific section of the BalloonSat.

**Accelerometer**

Project UFS will be using an accelerometer to measure the acceleration of the BalloonSat during its flight. Also, the accelerometer will measure ascent rates and descent rates of the flight string in accordance with time data. The accelerometer is connected to Arduino 1 which houses the main scientific instruments. Data will be recorded to a SD shield connected to Arduino 1. The accelerometer has been provided by the Colorado Space Grant Consortium (COSGC).
**Temperature Sensors**
Project UFS will be using three temperature sensors to measure temperature during flight. One temperature sensor will be used to measure the internal temperature of the main compartment of the BalloonSat and will be connected to Arduino 1. The second temperature sensor will be used to measure the external temperature at various altitudes during flight. This temperature sensor will be connected to Arduino 1. The data from the first two temperature sensors will be stored on an SD Shield connected to Arduino 1. The third temperature sensor will be a part of the experiment and will be measuring the internal temperature inside the experiment compartment. This temperature sensor will be connected to Arduino 2 and the data will be stored to an SD Shield connected to Arduino 2. The first two temperature sensors have been provided by COSGC and the experimental temperature sensor has been bought from SparkFun Electronics.

**Humidity Sensor**
Project UFS will be using a humidity sensor to measure the change in humidity during flight. The humidity sensor will be connected to Arduino 1 and the data will be stored on a SD Shield. The humidity sensor has been provided by COSGC.

**Pressure Sensor**
Project UFS will be using a pressure sensor to measure the variance in pressure with respect to altitude during flight. The pressure sensor will be connected to Arduino 1 and data will be stored to an SD Shield connected to Arduino 1. The pressure sensor has been provided by COSGC.

**Ultrasonic Sensor**
Project UFS will be using an ultrasonic sensor as part of experiment to measure the speed of sound at various altitudes. The ultrasonic sensor will be placed in the experimental compartment and will record data which will be used to calculate the speed of sound at various altitudes. The ultrasonic sensor will be connected to Arduino 2 and the data will be stored to an SD Shield connected to Arduino 2. The ultrasonic sensor has been bought from SparkFun Electronics.

### 3.3.2 C&DH Design
Throughout its ascent and descent, Project UFS will record humidity, pressure, temperature, and ultrasonic data points every ten seconds using two Arduino Unos. Time, humidity, pressure, and temperature will be simply recorded onto an SD card through an OpenLog with the Arduino function Serial.print(). The ultrasonic data is recorded in a similar way but to a different SD card in a different OpenLog. Every ten seconds, the ultrasonic sensor will emit a ping and measure the time it takes the ping to reach the wall.
of the BalloonSat and return to the sensor. This time value will be converted into a distance by the ultrasonic sensor, then recorded onto the SD card. Using this measured distance value and the known distance between the ultrasonic sensor and the rebounding wall, the Arduino will be programmed to calculate the actual speed of sound and record it onto the SD card as well.

### 3.3.3 Power Design

Project UFS has several scientific instruments and components that will require continuous power during flight. Our Power design consists of having a sufficient power source for each separate system (i.e. Arduino circuit 1, Arduino circuit 2, the Heater circuit, and the GoPro). Arduino circuit 1 will be connected to a 9V battery which will provide power when switched on before launch. Arduino circuit 2 will also be connected to a 9V battery which will provide power when switched on before launch, like Arduino circuit 1. The heater will be powered by three 9V batteries connected to a switch, which will be turned on right before launch. The GoPro has its own built-in lithium ion battery which will provide power to it throughout the duration of the flight for taking images.

### 3.3.4 Electrical Systems/Switches Design

Project UFS has a total of 3 switches; there are two switches for the two Arduino Unos, and one switch connected to the heater circuit. Each switch has an LED indicator to verify that the switch has either been turned on or off. The switches provided by the Gateway to Space program shall be protected sufficiently with the foam core structure to ensure minimal damage to them. The GoPro is an independent electrical system and shall be turned on using its own power button to take images during the flight. The GoPro also has its own LED indicator for its power status.

### 3.3.5 Thermal Design

The thermal system within the BalloonSat consists of an isolated heater circuit to prevent damage to the sensors and other electronic components due to the extreme cold (close to -80°C) of the upper atmosphere. Along with the heater circuit, the BalloonSat will have an outer structure made of foam core, and an inner lining of a foam insulation to further retain heat for the inner subsystems. The internal temperature of the BalloonSat shall not drop below -10°C, as per the requirement in the Spring 2017 Request for Proposal, and Panic! at the Cantina will ensure that the thermal subsystem of project UFS can fulfill this requirement with a Dry Ice Test. It is important that the heater interferes with the ultrasonic sensor as little as possible, as variations in temperature would surely affect the ultrasonic data. For this reason, the heater will be located opposite the ultrasonic sensor chamber. The ultrasonic sensor will be in the sound chamber which will be isolated by additional foam core and insulation to limit the effect on the sensor data from the heater circuit.
3.3.6 Imaging Design

Project UFS shall be equipped with a GoPro Hero4 Session camera provided by COSGC. The GoPro shall take 12 megapixel photos and later shall be converted into a time-lapse video to document the course of the flight. The camera is equipped with a 32GB MicroSD Card and an adapter is provided to transfer pictures onto a computer.

3.4 Data Retrieval & Analysis

Both Arduinos will record the measured sensor data to their own respective SD card through separate OpenLogs. The data will be stored using the Arduino’s built in coding function Serial.print().

When the BalloonSat returns to the ground, Panic! at the Cantina will recover the SD cards and will analyze the collected data. The altitudes during the flight will be calculated based on different temperature, humidity, and pressure measurements so that all together, these variables may be compared to the speed of sound data collected to formulate a conclusion to the stated hypotheses.

3.5 Concept of Operations

Prior to launch, Project UFS shall have its structure and software fully completed, and shall undergo a final system check to ensure all environmental sensors, the ultrasonic sensor, and the GoPro are fully functional to collect data throughout the flight. On launch day (April 8th, 2017), team Panic! at the Cantina shall turn on all switches, and check if the BalloonSat is completely sealed to guarantee a successful take-off. During the ascent, the environmental sensors and the ultrasonic sensor will collect data every ten seconds and record it to the onboard SD Shield. Also during ascent, the GoPro will take a picture every ten seconds. At an altitude of approximately 30km, the weather balloon will burst. While the accelerometer will be collecting data throughout the entire flight, the data collected during burst will be the most insightful for the magnitude of the BalloonSat’s orientation since it will be violently thrashing. During descent, all sensors onboard and the GoPro shall continue to collect data every ten seconds. Once the BalloonSat has landed and has been located, team Panic! at the Cantina shall first take pictures of the BalloonSat’s condition before handling it. Then, all switches shall be turned off to cease the collection of data. The data shall be analyzed by retrieving each SD card and transferring their data onto a computer to track, compare, and plot it in Microsoft Excel. The GoPro’s pictures will be transferred to a computer similarly. The stages of its flight are depicted in Figure 9 on the next page.
3.6 Functional Block Diagrams

Functional Block Diagrams are an integral part of managing the various electrical systems on board the BalloonSat. Panic! at the Cantina will use a setup consisting of four circuits: two Arduinos, a camera, and a heater. Both Arduino circuits will be powered by a 9V battery, with the power toggled by a switch and an LED to indicate that the system is powered. Arduino 1 will monitor and collect data on temperature (internally and externally), acceleration, humidity, and pressure during flight. Arduino 2 will calculate and record the speed of sound at varying temperatures, altitudes, and pressures, using an ultrasonic sensor and a second internal temperature sensor to monitor the internal temperature next to the ultrasonic sensor. The independent heater circuit will be powered by three 9V batteries, and, like the Arduinos, will have a switch and an LED to indicate system power. The camera (GoPro Hero 4 Session) is powered by its own internal battery and has its own LED indicating the power status.
4.0 Management

_Panic! at the Cantina_ will be managed efficiently and effectively by two project managers, each overseeing one specific aspect of UFS: as the Schedule Manager, Matt Weber will oversee making sure the BalloonSat is on track to be ready before launch day. Will Applegate, the team’s Budget Manager, will keep track of _Panic! at the Cantina’s_ expenditures and ensure the team does not go over the given budget.
4.1 Management Organization Chart

Each of the five subsystems in UFS will be worked on by two or three group members, meaning each of the eight members of Panic! At the Cantina will be on two subsystems. While each subsystem does not have a specific subsystem leader, the project managers will oversee each subsystem’s members to ensure they are on track and on time to complete their work.

4.2 Team Member Information

Below is a list of the names, email addresses, and the subsystems of each member in Panic! at the Cantina:

- Will Applegate | wiap9476@colorado.edu | Project Co-Manager, Budget Leader, Power
- David Cease | David.Cease@colorado.edu | Structural, C&DH/Software
- Michael Dynakowski | Michael.Dynakowski@colorado.edu | Structural, Thermal
- Prem Griddalur | prem.griddalur@colorado.edu | C&DH/Software, Power
- Griffith Kull | harry.kulliv@colorado.edu | Structural, Science
- Odysseus Quarles | Odysseus.Quarles@colorado.edu | Thermal, Power
- Matthew Ryan | Matthew.J.Ryan@colorado.edu | C&DH/Software, Science
- Matt Weber | mawe8722@colorado.edu | Project Co-Manager, Schedule Manager, Science

4.3 Schedule

Panic! at the Cantina will hold team meetings every Tuesday starting at 4:00pm and every Saturday starting at 12:00pm to complete project UFS on time. More meetings will be added to meet deadlines when needed. Below is the schedule that Panic! at the Cantina will stick to in order to stay on top of work and not get stuck cramming and making mistakes close to deadlines.
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<td>Proposal Completed</td>
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<tr>
<td>2/20-2/26</td>
<td>Refine CAD models and begin planning and building structures</td>
</tr>
<tr>
<td>2/27-3/5</td>
<td>Preliminary Design Review Presentation Completed</td>
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<td>3/6-3/12</td>
<td>DD Rev C assigned</td>
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<tr>
<td>3/13-3/19</td>
<td>Payload inspection, science, sensors, and ultrasonic sensor coding completed Cold testing Mid Semester Team Evaluations due 3/14</td>
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<td>3/20-3/26</td>
<td>RFF Cards Assigned</td>
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<tr>
<td>3/27-4/2</td>
<td>Spring Break: Team keeps in touch and completes any tasks needed (Launch Readiness Review Presentation)</td>
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<tr>
<td>4/3-4/7</td>
<td>Finalize and have fully functional BalloonSat</td>
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<td>4/8</td>
<td>LAUNCH DAY - 6:50AM in Windsor, Colorado</td>
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<td>4/9-4/16</td>
<td>DD Rev D assigned</td>
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<tr>
<td>4/30-5/10</td>
<td>Complete Final presentation</td>
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5.0 Budget and Weight

Project UFS shall use approximately 741g (+/-50g for unexpected materials) of the allowed 864g, and $16 (+/-$50 for unexpected materials) of the $180 budget. For spare materials, such as test batteries and dry ice, Panic! at the Cantina is expecting to spend approximately $45 out of pocket. All other purchases will go through a request and approval process with Chris Koehler, and will be purchased using Chris’ CU Visa Card. Receipts will be turned in within 2 days of purchase. This budget will be managed by Will Applegate, and Panic! at the Cantina will hold themselves accountable for all purchases and budgetary restraints. Also, all provided hardware is the property of the Gateway to Space program and thus will be returned in proper working order at the end of the semester.

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<tr>
<td>Unexpected materials</td>
<td>-</td>
<td>Varied +/-50g</td>
<td>Add +$50</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>741g (+/- 50g)</strong></td>
<td><strong>$16 (+/- $50)</strong></td>
<td></td>
</tr>
</tbody>
</table>
6.0 Testing and Safety

6.1 Test Plan

To prepare for the extreme conditions during flight, project UFS shall undergo multiple tests designed to analyze survivability during common scenarios such as turbulence, extensive structural stress, subzero temperatures, and high accelerations. In addition, all sensors and electronics will be calibrated, tested, and verified to work in conditions ranging from ground level pressure and temperature to intense subzero temperatures and low pressures, to ensure they will function adequately throughout the entire flight. With frequent and thorough testing, project UFS shall return from the flight in such a condition that it will be fully functional for a subsequent flight.

6.1.1 Structural Tests

**Whip Test**

*Panic! at the Cantina* will utilize a whip test to test the BalloonSat under high-g situations. This test is integral because immediately following burst during the flight, the BalloonSat will be subject to high accelerations as it plummets back toward Earth’s surface, potentially exceeding Mach 1 during descent. *Panic! at the Cantina* will conduct this test by attaching the BalloonSat to a tight rope and spinning it at high speeds, generating large centripetal forces. This test will be conducted in an isolated area away from buildings and windows to make the test successful and safe for project UFS and the CU Boulder students and campus.

**Drop Test**

During the descent, one factor *Panic! at the Cantina* must consider is the impact that project UFS will encounter as it hits the ground at approximately 50 km/hr, assuming an optimal chute deployment. Due to the high velocity impact, project UFS must be well constructed to prevent damage to internal subsystems. *Panic! at the Cantina* will drop the BalloonSat from various heights, such as the ITLL Balconies, to study which areas of the BalloonSat suffer the most damage. This test will reveal critical structural flaws which will be eliminated to ensure survivability. These drop tests will be performed with no other people and fragile objects around to reduce the risk of hurting people and breaking objects to zero.

**Stair Test**

*Panic! at the Cantina* will also conduct a stair test to simulate the impact the BalloonSat will be subjected to during landing. This test is simply kicking project UFS down a flight of stairs, such as the staircases in the DLC building, to test the strength and durability of the structure. The stair test is crucial as *Panic! at the Cantina* must make sure that project UFS can handle a harsh and chaotic landing without damaging any key internal parts of the BalloonSat. The stair test shall be conducted in a safe environment, away from other people and members of *Panic! at the Cantina* to reduce the risk of injuries. Also, any fragile objects or windows will not be nearby when this test is conducted to avoid damages suffered to CU’s campus or other people’s belongings.
6.1.2 Environmental Tests

Dry-Ice Test

During the flight, project UFS will encounter subzero temperatures possibly reaching -80°C. Although a heater circuit is included, temperature this low can damage the effectiveness of the power supply, hardware, and structural integrity. Panic! at the Cantina will place the fully equipped BalloonSat into a cooler of dry ice for 1 hour and monitor whether the subsystems and sensors are functioning correctly. The thermal subsystem is being heavily tested here to ensure that the foam core, insulation, and heater circuit combined keep the internal temperature above -10°C.

6.1.3 Ultrasonic Sensor / Camera Tests

To minimize failure and error for all sensors aboard the BalloonSat, Panic! at the Cantina will test each sensor individually to ensure they record, analyze, and store the correct data. Specifically, the ultrasonic sensor will be tested to make sure it works correctly and that the pre-programmed code does not require updates or alterations to appropriately calculate the speed of sound. All connections between the sensors and the Arduinos must be carefully tracked to ensure all sensors are treated independently and leave no room for error.

To capture the entire flight experience, project UFS is equipped with a GoPro Hero4 Session camera. The GoPro shall capture 12mp photos for the duration of the flight; however, to test the longevity of the battery, team Panic! At the Cantina will test the GoPro taking 12mp photos for 2.5 hours and determine whether this setting will last as long as the flight time; along with, choosing the correct shutter speed in capturing these photos.

6.2 Safety

To prevent any injuries and maintain a safe working environment, Panic! at the Cantina will maintain several safety measures. When team members are soldering, there is a second member assisting and making sure the other member is not burned by the soldering iron. In addition, during all tests for which the BalloonSat will be in motion, all team members except those necessary to complete the test will remain at a safe distance away. These tests will take place away from windows, people, and fragile objects.

7.0 Expected Results

Panic! at the Cantina expects to see that many atmospheric components will have an impact on the speed of sound at any given altitude, but temperature will have the largest correlation coefficient when plotted against altitude. This is expected, since additional heat will allow the atoms in the medium to move more quickly. We hope to discover how heavily the speed of sound is based off temperature as opposed to humidity or pressure.

7.1 Completed Arduino Tests

Panic! at the Cantina has successfully tested taking data by testing each sensor and measuring them. Each sensor was connected to the Arduino, which communicates with a computer through a cable and the Arduino program. The temperature sensor data was measured as a member put his hand around it, and the temperature rose and subsequently fell accordingly. The humidity sensor data was measured as a member exhaled on it, and the humidity rose and subsequently fell accordingly. The pressure sensor data was measured as a member sucked on it,

Anahid Blaisdell 3/10/2017 10:24 PM
Comment [28]: This didn’t show up in Word so I’m not sure what should be here.

Anahid Blaisdell 3/11/2017 2:01 PM
Comment [29]: How is it going to be tested? Like you’re going to run it and find the speed of sound at ~5,600 ft and compare to the theoretical speed of sound at this elevation? You have to describe the test here and how you calibrate it.

Anahid Blaisdell 3/10/2017 10:24 PM
Comment [30]: If you italicize everywhere else, you gotta italicize here too.

Anahid Blaisdell 3/10/2017 10:25 PM
Comment [31]: This should be a comma not a semicolon

Anahid Blaisdell 3/10/2017 10:25 PM
Comment [32]: Add that they’re wearing safety glasses.

Anahid Blaisdell 3/11/2017 1:13 PM
Comment [33]: I would say “faster” instead of more quickly.

Anahid Blaisdell 3/10/2017 10:31 PM
Comment [34]: Good goal! I’d like to see that comparison.

Anahid Blaisdell 3/11/2017 2:03 PM
Comment [35]: I know this is completed, but you still have to add this to the test section.

Anahid Blaisdell 3/11/2017 1:13 PM
Comment [36]: I would say “faster” instead of more quickly.
and the pressure rose and fell accordingly as well. The accelerometer data was measured as a member rotated the device in the x and z directions. The transmitted x and z data had a range from -1 to 1 accordingly. The final data is accessible via an Excel-convertible text file for analyzation.

![Figure 10 - Arduino Test of Internal Temperature Sensor and External Temperature Sensor](image1)

![Figure 11 - Arduino Test of Humidity Sensor](image2)
Figure 12 - Arduino Test of Pressure Sensor

Figure 13 - Arduino Test of Accelerometer
Panic! at the Cantina expects the actual recovered data to show that temperature is directly proportional to the speed of sound, while factors such as humidity and pressure have lower correlation coefficients with the speed of sound. This will mean that as the BalloonSat ascends through the Troposphere, the temperature and speed of sound shall go down. As the BalloonSat ascends partially into the Stratosphere, the temperature and hence the speed of sound will climb upwards before burst.

### 7.2 Temperature Sensors

![Camera Temperature Data varying with time](image1.png)

*Figure 14 – Camera Temperature Data varying with time*

![External Temperature at varying times](image2.png)

*Figure 15 – External Temperature at varying times*
Panic! at the Cantina expects its temperature data to vary accordingly with time, with critical points as the BalloonSat enters and leaves the stratosphere and at burst. In Figure 14 is actual data from another BalloonSat mission, Project Hollands.\(^6\) In Figure 15 is more real data from Team KC, another BalloonSat measuring external temperature during its trip.\(^7\)

### 7.3 Pressure Sensor

![Figure 16 - Pressure Readings with respect to Time\(^8\)](image)

Panic! at the Cantina expects its pressure data to vary accordingly with pressure, with a sole critical point at burst. Figure 16 depicts actual data recorded at Nevada University of pressure versus time.\(^8\)

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7.4 Humidity Sensor

Panic! at the Cantina expects the humidity data to vary accordingly, such as the plot in Figure 17. There are critical points transitioning into the stratosphere and at burst. In Figure 18, actual humidity data measured by NOAA is plotted.

Figure 17 - Expected Humidity Data during flight

Anahid Blaisdell 3/10/2017 10:38 PM
Comment [41]: Increase size of legend.
Anahid Blaisdell 3/10/2017 10:38 PM
Comment [42]: Format this graph so that it is more easily readable. Right now, it’s really narrow and small.

Figure 18 - NOAA Plot of Humidity Sensor readings versus Altitude

Anahid Blaisdell 3/10/2017 10:38 PM
Comment [43]: Increase size of legend.
7.5 Accelerometer

Panic! at the Cantina expects the accelerometer data to vary with time accordingly as the BalloonSat rotates through the air, as seen in Figure 19.

Figure 19 - Expected Accelerometer Data