Comment [1]: Overall a nice job. A few more details on how your sound recording works would have been helpful but a very good start overall.
1. Overview and Mission Statement

1.1 Mission Overview

Project Jumpman is a high altitude BalloonSat mission for the ASEN 1400 course, designed to record and analyze the transmission of various sound frequencies (in terms of frequency distortion and loss of amplitude) as pressure decreases, as well as observe the overall environment around the BalloonSat. By analyzing the collected data, team Flying Through the 6 With My Woes will be able to better understand how sound waves travel in various pressured environments, up to a maximum of 30 km above sea level. This topic of study interests team Flying Through the 6 With My Woes because of its relation to infrasound waves traveling into near space after strong tectonic movements on Earth. After the Earth’s crust shifts, the movement produces vibrations in the atmosphere, sending low frequency sound waves into near space. By verifying that low frequency sound waves are relatively detectable in near space, Team Flying Though the 6 With My Woes can add weight to the possibility of detecting and gathering information on oceanic earthquakes and other tectonic movements, which may cause natural disasters such as tsunamis.

1.2 Mission Statement

Team Flying Through the 6 With My Woes will design, build, and launch a BalloonSat with the purpose of investigating how various pre-determined sound frequencies change as pressure and altitude changes during flight. The changes in frequency will be analyzed in terms of the change in amplitude and frequency distortion of the various sound waves and will be compared to the pressure and altitude readings to determine how sound waves travel at various pressured environments.

1.3 Hypothesis and Expected Results

Project Jumpman is a mission focused on the change in amplitude and frequency distortion of sound waves. When objects move - for example, a vibrating string on a violin - air molecules around the object will bump into other air molecules, which bump into more air molecules, which continue through the air as a wave of changing air pressure. This wave reaches human ears and is perceived as sound. Sound is measured in units denoted as Hertz. One Hertz is one oscillation of the changing air pressure per second. The frequency of sound waves relates to the pitch of the sound; sounds with longer wavelengths have a lower frequency and are perceived as a lower pitch. ¹ The amplitude of the sound waves relates to the volume of the sound; sounds with larger amplitudes are perceived at a higher volume. Humans perceive sound between the frequencies of approximately 20 Hz and 20 kHz.² Sound waves below approximately 20 Hz (called infrasound waves) are inaudible to human ears.

Project Jumpman will be sending a BalloonSat to a maximum of 30 km above sea level. At this altitude, the air is too thin for audible sound waves to travel. But this air can carry the lower frequency infrasound waves. During crust shifts on the Earth, vibrations are produced in the atmosphere that can carry into space. In March 2011, during a magnitude 9.0 earthquake in Japan, the Earth’s movement created low frequency vibrations that traveled into the atmosphere. These infrasound waves traveled to “the European Space Agency’s Gravity Field and Steady-

The BalloonSat will contain 3 sound emitting devices (“speakers”), producing 3 different frequencies; a lower level frequency at 100 Hz, a mid-level frequency at 550 Hz, and a higher level frequency at 1000 Hz, and 3 microphones which will detect the vibrations produced by the speakers. Team Flying Through the 6 With My Woes hypothesizes that the propagation of low frequency sounds in low pressure environments is greater than the propagation of higher frequency sounds in the same environments.

2. Technical Overview

2.1 Structure

Main Experiment:
Team Flying Through the 6 With My Woes will conduct an experiment that records three different frequencies of sound waves as the BalloonSat ascends into a lower pressure environment in order to prove that low frequency sound waves can travel through near space. The frequencies will be recorded in a 25 cm x 25 cm x 25 cm cube, which will give sufficient space to conduct the experiment. The three frequencies will be emitted by three separate speakers, located in the corners of the cube, attached to the roof of the BalloonSat. Three microphones will lie opposite the speakers, on the bottom of the satellite. The speakers and microphones will be placed in the corners to obtain maximum distance between the sound emitting devices, in order to reduce signal overlap. Each speaker/microphone pair will be surrounded by a carbon-fiber cylindrical tube, lined with a sound-insulating foam.

Internal Design:
The Jumpman BalloonSat consists of two Arduino Unos, various sensors, the sound experiment system, a heater unit, three 9V batteries, two AA batteries, a camera with a two-GB SD card, three switches, LEDs, an extra battery, and insulation. There will be a cylindrical section of the satellite cut out in its center so that it may be attached to the balloon. The two Arduinos will be

Figure 1: Exterior design and Dimensions

Figure 2: External Design (Top View)
placed next to each other, as will the two 9V batteries. All the sensors will be placed on the sides of the BalloonSat, and will not be placed on the floor or ceiling. The rest of the space will be used to place the heater and camera on the bottom of the satellite. The camera will be pointing out to the side, in order to achieve a stunning view of the curvature of the earth.

Figure 3: Internal View

External Design:
The materials used to build the structure of the satellite will be primarily foam core, aluminum, duct tape, and hot glue. The flap or door used to provide access to the interior of the satellite will be constructed using the additional material of velcro.

Obtaining Materials
Most materials (such as foam core, thermometers, pressure sensor, Arduino Uno boards, 5 9V batteries, accelerometer, humidity sensor, heater, and camera) will be obtained through the Gateway class. However, materials such as sound insulation, speakers, cylindrical tubes, and microphones will be purchased either through Sparkfun or other websites. The cylindrical tube used to attach the satellite to the balloon will be provided by CU Boulder.

2.2 Electrical System
The electrical system consists of two Arduino Unos, various sensors (internal/external temperature, tri-axis accelerometer, pressure sensor, and heater), microphones, speakers, the heater unit, and the systems used to power those devices, which consists of 9V batteries, switches, and LEDs. The camera, including the 2GB SD Card, is not necessary to the scientific mission, but is included purely for viewing pleasure. The primary internal components used for the experiment are the microphones and speakers. The sound waves generated by the speakers will be received and recorded by the microphones, and written to the SD card as raw data by the Arduino. LEDs and switches used in the power system will be attached to the wall closest to the Arduinos.

2.3 Thermal System
The thermal system of the satellite is an essential part to the success of the mission. Without a heater and foam core, many of the systems would simply stop working due to extreme temperatures. The provided internal heating element will be placed inside the BalloonSat. The heater will be placed a sufficient distance from other hardware so as to not cause damage due to heat. The BalloonSat will be insulated in a way sufficient to ensure that the internal temperature remains above -10°C while the heater is in operation.

2.4 Software/C&DH

Flying Through the 6 With My Woes
Data from the sensors will be stored using the supplied SD card shields. Each Arduino Uno will have one SD card shield, to which it will be writing raw data every minute for the duration of the mission. The data will be stored in the form of a standard text file, with each line representing one twenty minutes of data. After retrieval of the BalloonSat, the data will then be copied from the two SD cards onto two separate computers, to ensure that none of it is lost. Post-mission data analysis will consist of one or more computer scripts, which will convert the raw data into human-readable formats. The camera will also include a 2GB SD card to store multiple photos of the curvature of the Earth.

2.5 Special Features
For the mission, the BalloonSat will have the specialized science equipment and consequent accommodations. To isolate the sound equipment, Project Jumpman will be incorporating a sound-insulating foam around the experiment chambers. This will also make fitting the components more difficult, but the net internal volume will decrease, and consequently will maintain a more constant temperature.

2.6 Functional Block Diagram

Flying Through the 6 With My Woes
2.7 Testing and Safety:

To ensure a successful and worthwhile mission, the Jumpman BalloonSat will be subjected to conditions of extreme stress meeting or exceeding those expected during the flight, so as to ensure that it will survive the mission entirely intact, so that it may be returned in perfect working order to the Gateway to Space program at the end of the current semester. These conditions include jostling at burst and impact, battering after touchdown, and experiencing extreme temperatures through the tropopause. Tests will include the whip test, drop test, stair test, dry ice test, sensors/science testing, camera testing, and a mission simulation test.

Whip Test:
The whip test is designed to simulate the forces acting upon the BalloonSat directly after the burst of the balloon before the more controlled parachute descent. This test consists of attaching the structure (filled with simulation mass as to save actual hardware in case of failure) to the end of cord and swinging violently above the head and around the body. By swinging as quickly as possible away from other people and objects, the person swinging the structure and simulation mass will attempt to create the most reasonable extreme conditions which the BalloonSat will undergo right after burst.

Drop Test:
The drop test consists of dropping the structure of the BalloonSat from 10 meters. This test simulates the impact of the BalloonSat with the ground at the end of the mission. Simulation masses will again be placed inside to avoid damaging actual hardware while damage to structure can still be observed. This test can be dangerous and will not be done above any people or breakable objects.

Stair Test:
The stair test involves propelling the BalloonSat down a set of tall stairs (at least 5 meters) to create conditions close to those which the BalloonSat may experience if the parachute rig drags the payloads across the ground after impact. To test this, the BalloonSat will be filled with simulation mass and kicked down a flight of stairs. Precautions to ensure safety include wide berth of no-entry zone at the bottom of the stairs and on the stairs while the test is in progress.

Temperature Test:
The dry ice/temperature test is designed to test the craft’s ability to function at very low temperatures. Temperatures at 30 km can approach -70°C, so the BalloonSat should be verified functional with environmental temperatures reaching this low. This test will be performed by placing the BalloonSat in a cooler surrounded by dry ice for three hours while all electronics operating. This will test the heater, battery life, and sensors. Gloves will be worn handling the dry ice and it will be handled responsibly to ensure no harm to people or property.

Sensor Testing:
Sensor testing includes testing all sensing equipment on the craft. Each piece of required environmental sensing will be tested and calibrated individually. Additionally, the microphones and speakers will all be tested individually to ensure proper performance. An extra step to be taken during this process includes activating each speaker and separate microphone in the setup (so that the microphone paired to that speaker is off and another pair’s microphone is listening) to make sure there can be no sound overlap during the experiment.

Camera Testing:
The camera will be tested during the temperature test. This will prove the camera’s abilities to operate in cold temperatures as far as battery life and storage space when it is operating for the three hours. Additionally, the camera will be tested briefly outside the cold test to ensure that it
works while inside the structure and that the resulting photographs are clear. The camera will also be tested during the mission simulation test in order to prove that it can endure for the duration of the mission.

**Mission Simulation Test:**
This test will be a simulation of the entire mission on the ground. All sensors and equipment will be powered and collecting data for three hours. The goal of this test is to prove that all of the equipment can function simultaneously for the expected mission length.

**2.8 Other Safety:**
In addition to all safety precautions taken during testing, safety will be addressed during every team interaction. Soldering will be done with safety glasses and proper supplies. Also, any other machine or tool will only be operated by qualified members and according to intended use. Finally, no testing will be done individually in order to minimize risk for serious injury.

**2.9 Mission Requirements**

**Data Acquisition and Retrieval**
As mentioned above, the data will be scripted to SD cards during flight and retrieved post-flight and put onto at least two computers.

The BalloonSat will be equipped with an array of three sound emitter/receiver pairs, for the purpose of recording changes in the received sound waves due to changes in air pressure. Each emitter/receiver pair will be set at a different frequency: the first at 100 cycles per second, the second at 550, and the third at 1000. The difference in the change in amplitude between the three frequencies will be analyzed, and it is expected that the lower frequencies will diminish less in amplitude than the higher sounds. The provided accelerometers shall be used to record the ascent and descent rates of the BalloonSat during the mission. This data shall be retrieved at the end of the mission and converted into human-readable format for analysis.

**General Construction and Structural Integrity**
Also detailed above, Project Jumpman will undergo thorough and rigorous testing to ensure a successful mission; including structural, heating, sensor, and mission testing. The BalloonSat will be weighed frequently, and at no time will any addition be allowed which increases the weight beyond the specified limit of 864 grams.

The provided external temperature sensor will be mounted 1 inch from the top of the BalloonSat, so as to minimize the possibility of damage during landing. The provided Canon A3400 IS digital camera will be flown facing out and shall take one photo per minute. The camera will be equipped with a two-GB SD card; which capacity is the expected data storage requirement. The temperature will be recorded over time using the provided internal temperature sensor, and the data analyzed to confirm proper heater function.

The BalloonSat will be constructed using the provided sheets of foam core, in order to minimize weight while maintaining sufficient stability and structural integrity. Parts of a quantity above the expected requirements shall be budgeted for, in order to ensure that the project remains under budget.

Team contact information will be clearly marked on the outside of the BalloonSat unit, in order to minimize the possibility of being unable to retrieve the satellite after landing. The provided flag of the United States of America will also be placed in a clearly visible location on the BalloonSat.
3. Management

3.1 Management structure

Project Jumpman is led by Jarrod Puseman, elected team manager, and vice manager Aubrey Kroger. Each individual subsystem of the craft will be managed by a primary and a secondary, with minor help from the rest of the team. The Software Design team, led by Declan Murray with Selasi Etchey as the secondary, will be in charge of writing the code for the Arduino boards, as well as making any necessary software modifications as the project moves forward. The Power division is led by primary Collin Brockway, and assisted by secondary Declan Murray. The goal of the Power division is to find a feasible way to power the craft, without compromising the weight limit of the Balloon Sat. The Science Department, led by Aubrey Kroger with Emily Weidenfeller as secondary, will be in charge of designing and testing the experiment of the craft. The Structure team, made up of Emily Weidenfeller as primary and Collin Brockway as secondary, will design and build the craft, both internal and external components. The C&DH team (Command & Data Handling), led by team manager Jarrod Puseman and assisted by secondary Aubrey Kroger, will be responsible for retrieving and analyzing data from the flight. The Thermal department, led by primary Selasi Etchey and assisted by secondary Jarrod Puseman, will be in charge of the making sure thermal functions on the craft, such as the system heated, are functional and efficient.

3.2 Team Information

Declan Murray
- Phone Number: [Redacted]
- School: The University of Colorado at Boulder
- Address: Andrews Hall W322, 2510 Kittredge Loop Road
- Special Skills: Very hands on, great coordination, high propensity to learn

Aubrey Kroger
- Phone Number: [Redacted]
- School: The University of Colorado at Boulder

Flying Through the 6 With My Woes 7
Emily Weifenfeller
- Address: Kittredge Central S212, 2480 Kittredge Loop Dr
- Special Skills: Experience with music and sound from Music Theory

Collin Brockway
- Phone Number: [Redacted]
- School: The University of Colorado at Boulder
- Address: 220 Aden, 2320 Libby Dr.
- Special Skills: Proficient in drawing and design/ Has experience with Autodesk software

Jarrod Puseman
- Phone Number: [Redacted]
- School: The University of Colorado at Boulder
- Address: 113 Andrews Hall, 2510 Kittredge Loop Dr.
- Special Skills: Well versed in software programming and embedded systems

Selasi Etchey
- Phone Number: [Redacted]
- School: The University of Colorado at Boulder
- Address: 1130 Hallett, 2250 Willard Loop Dr.
- Special Skills: Background in Business Management experience in Finance

3.3 Budget and Financial Information
The team budget will be managed by Selasi Etchey. Selasi Etchey plans to make sure that the team keeps its budget by accounting for spare parts in the cost of the project. All materials have possible extra costs accounted for in the budget spreadsheet. All changes to the initial budget proposal will be brought up to Selasi for approval.
3.4 Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team meetings</td>
<td>Every Monday, Wednesday, and Friday from 3pm to 5pm</td>
</tr>
<tr>
<td>Hardware order form submitted by</td>
<td>9/23/2016</td>
</tr>
<tr>
<td>Working prototype design complete by</td>
<td>Friday 9/23/2016</td>
</tr>
<tr>
<td>All hardware acquired by</td>
<td>Monday 9/26/2016</td>
</tr>
<tr>
<td>Preliminary design complete by</td>
<td>Tuesday 10/04/2016</td>
</tr>
<tr>
<td>Design Rev A/B Due</td>
<td>10/11/2016</td>
</tr>
<tr>
<td>Final system ready for testing</td>
<td>Wednesday 10/19/2016</td>
</tr>
<tr>
<td>(and working test programming) complete by</td>
<td></td>
</tr>
<tr>
<td>Final programming complete by</td>
<td>Wednesday 10/26/2016</td>
</tr>
<tr>
<td>In-class mission simulation test</td>
<td>11/03/2016</td>
</tr>
<tr>
<td>LRR Slides Due</td>
<td>11/08/2016</td>
</tr>
<tr>
<td>Design Rev C Due</td>
<td>11/10/2016</td>
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<tr>
<td>LAUNCH DAY</td>
<td>11/12/2016</td>
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<tr>
<td>Quick Look Slides Due</td>
<td>11/17/2016</td>
</tr>
<tr>
<td>Design Rev D Due</td>
<td>12/03/2016</td>
</tr>
<tr>
<td>Video Due</td>
<td>12/03/2016</td>
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<tr>
<td>ITLL Design Expo</td>
<td>12/03/2016</td>
</tr>
<tr>
<td>Final Presentations</td>
<td>12/06/2016</td>
</tr>
<tr>
<td>Hardware Turn In</td>
<td>12/08/2016</td>
</tr>
</tbody>
</table>

4. Miscellaneous

All measurements will be done in SI. Sufficient precautions will be taken so as to ensure that no team member is physically harmed in the process of building the BalloonSat. A hardware order form with the budgeted materials shall be submitted to Professor Koehler so that he may order the required hardware. Any future purchases shall be submitted for approval prior to purchase, and, post-purchase, duly recorded and submitted in receipt form in order that a complete record might be kept. Visual indications shall be placed on the outside of the BalloonSat such that it is easy to determine whether the system is functioning properly. Team Flying Through the 6 With my Woes intends to complete all of the above-mentioned tasks well within the specified time limits.