StAIRWave to Heaven

Team Seven Nation Army

<table>
<thead>
<tr>
<th>James Roberts</th>
<th>Chris Galena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyara Ochart</td>
<td>Garrett Bell</td>
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<tr>
<td>Alexis Wall</td>
<td>Kelly Crombie</td>
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<tr>
<td>Grant Hupp</td>
<td></td>
</tr>
</tbody>
</table>
Section I. Overview and Mission Statement

1.a Mission Overview

Stairwaves to Heaven (hereinafter referred to as ‘the Mission’) is a proposed balloon satellite to be conducted by the undergraduate student group, Seven Nation Army, (hereinafter referred to as ‘the Team’) from the University of Colorado at Boulder for the ASEN 1400 course whose objective is to observe changes in the properties of sound waves, namely frequency and amplitude, as atmospheric pressure and temperature change with altitude up to 30 kilometers. In doing so, the Mission will also collect data pertaining to the Mission’s surrounding environment in order to identify other potential causes for changes in sound properties and to reduce sources of error.

To achieve this, the Team will use various electronic sensors and components to fully automate all processes of the Mission, as outlined in section II of this proposal. Core to the Mission are a speaker device, which will, on a one minute interval, emit at a specific amplitude and frequency that are determined to be distinct from those that may result from wind noise at both ascent and descent velocities, and recording devices, which will capture flight audio as well as output an analog representation of amplitude that can be analyzed to determine frequency.

The Team hopes to contribute to the scientific understanding of sound propagation at high altitude. Sound is a primary source of human communication and as rates of technological advancement continue to increase, it is important to understand the properties of sound. In addition to the scientific purpose of the Mission, the Team believes that the experiences and knowledge to be gained through the construction and control of a rudimentary scientific satellite to be valuable in each member's future endeavors.

1.b Mission Statement

The Mission is to observe the effects of decreasing atmospheric pressure and changing atmospheric temperature on both the frequency and amplitude of sound waves using a balloon satellite which will emit sounds of a predetermined frequency and amplitude on a time interval and record flight audio for post-flight analysis. 

1.c Hypothesis

It has been well established that atmospheric pressure decreases with altitude. The ideal gas law shows that gas pressure is directly related to the number density of the gas, and while it is the case that the gas to be measured is far from ideal, the same principal holds true for Earth’s atmosphere. As such, the Team expects that there will be less gas in the upper atmosphere than there is at the Earth’s surface.

Furthermore, it is known that sound wave propagation requires a medium. As density of the medium decreases, the speed of the sound wave will increase as the speed of sound through a medium is inversely related to the medium’s density. Since wave speed and frequency are directly proportional, it follows that as density of the medium decreases the frequency of the sound will

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Stairwaves to Heaven

increase.

Additionally, due to the properties of density, the Team expects there to be less mass in the upper atmosphere than at the surface. Given that force is directly proportional to the mass of a system and assuming that the acceleration of the system is constant, the force exerted on a system will decrease as density decreases. As amplitude is a measure of the force of a sound wave over an area, a decrease in force will also decrease the amplitude. It is the hypothesis of the Team, therefore, that the frequency will increase and the amplitude will decrease as altitude increases due to the decrease in pressure.

Section II. Technical Overview

II.a Hardware

To complete the Mission, the Team will need to procure the necessary hardware and resources. The following hardware will be provided to the Team by the course instructor: GoPro Hero4 Session digital camera, two gigabyte secure digital (SD) memory card, two Arduino Unos, OpenLog microSD card shield, internal and external temperature sensors, pressure sensor, accelerometer, humidity sensor, heater kits, switches, three half sheets of black three-eighths inch foam core, batteries, aluminum tape and other required items. The sound sensors and speaker necessary for the scientific aspect of the Mission will be purchased through the electronic supply company Sparkfun. The Team will also need to purchase dry ice and rope for carrying out various tests which will be acquired at the King Soopers in Boulder at the expense of the members of the Team.

After procuring the hardware, the Team will test the hardware using various methods to ensure proper function of each material before integrating all the components of the Mission. After integration and construction is completed, further testing will be conducted to ensure the Mission will not fail in flight and to improve upon any potential flaws. All hardware will be supervised by the systems engineers, Chris Galena and Grant Hupp.

II.b Structure

The Mission will be housed in a foam core cube measuring 20 centimeters each side. A flexible tube running through the center of the top and bottom panels will be used to support the Mission on a rope attached to a balloon which will propel the Mission approximately 30 kilometers above Earth’s surface.
A speaker will be placed on a vertical panel of the Mission, and two sound sensors will be placed on the panel parallel to that of the speaker. To complete the construction of the Mission in an efficient manner, the hardware listed above will be utilized and a schedule has been created, as shown in section III.a of this proposal. All structures will be supervised by Chris Galena and Cyara Ochart.

II.c Thermal and Insulation

The thermal system is essential in keeping the Mission functional. Due to extremely cold temperatures that will occur as the Mission rises through the atmosphere, the heater and insulation are the only things keeping the sensors leaving their operational temperatures. Sensors can stop working at temperatures approximately -20°Celsius, so the goal of the heater is to keep the Mission above -10°Celsius. The insulation will surround the Mission and be placed in a location where it can equally warm all of the necessary systems without overheating them. All thermal systems will be supervised by Garrett Bell and Grant Hupp.

II.d Command and Data Handling

The Team will be equipping the Mission with Arduinos capable of autonomously running the mission once it is launched. The data will be written onto SD cards and analyzed using Matlab once the Mission returns to the ground. Prior to launch, the Arduinos will be programmed to write sound data and data from the other sensors onto the SD cards. All command and data handling will be supervised by Alexis Wall and Cyara Ochart.

II.e Electrical System

The electrical system will be composed of three independent systems. The first system is controlled by an Arduino Uno that will collect data on humidity, pressure, acceleration, and internal and external temperature. One nine-volt (9V) battery will supply power to this system, and data will be written onto a SD memory card also connected to the Arduino Uno. The second system will also consist of an Arduino Uno that controls a second SD card, a 2.048 kilohertz mini speaker that will emit a predetermined frequency and amplitude distinguishable from ambient noise on a one minute time interval, two sound sensors which will write audio data at each beep onto the SD card, and use a 9V battery for power. The final system will be a heater designed to regulate the flight temperature of the Mission (> -10 Celsius), connected to two 9V batteries for power. All electrical systems will be supervised by systems engineers, Chris Galena and Grant Hupp.
II.e Functional Block Diagram

II.f Science

Much of the science to be conducted will occur after the flight of the Mission in analysis of the data recorded by the sensors onto the SD cards. To test the Team’s hypothesis, statistical analysis and observations of the data will be conducted to identify fluctuations in sound frequency and amplitude as well as in pressure, temperature, and other atmospheric parameters in an effort to establish a correlation between these factors. In doing so the Team will be able to determine the potential causes of these fluctuations and draw a conclusion from the Mission.

To execute the Mission, two sound sensors will read and record data emitted from a single speaker. The sound sensors will be calibrated at the Integrated Teaching and Learning Laboratory (ITLL) using the speaker at its preset frequency at a distance of 19.8 centimeters from the speaker in standard conditions. Temperature sensors will read the internal and external temperatures of the Mission; the Team will calibrate these sensors by exposing them to ice water (0°C Celsius) and to boiling water (100°C Celsius). The accelerometer will be calibrated with the assistance of Tim May for accuracy by conducting drop tests and accounting for air resistance to ensure it is accurate in reference to gravitational acceleration. The pressure and humidity sensors will be calibrated in a standard environment with constant temperature, pressure, and humidity levels. These sensors will collect data that will be used in the Team’s post-flight analysis when determining the environmental causes of changes in sound wave frequency and amplitude. All scientific aspects of the Mission will be supervised by Garrett Bell and James Roberts.

II.g Data Retrieval

Once the Mission lands and is retrieved, the data that was collected during the flight will be uploaded to a computer for further analysis. Tracking and location data will be provided to the Team post flight, at which point the Team will drive to the landing location and retrieve the Mission. The data will then be transferred to a member of the Team’s hard disk drive for secure storage. Data retrieval will be supervised by the Team.
II. Testing and Safety

Considering the environmental extremes of the flight of the Mission, it is important that the Team tests the Mission in multiple situations to ensure the Mission will be able to withstand the conditions it will experience during the flight. The Team will use vacuum chamber, electronic, and structural testing in order to ensure minimal damage and errors during the flight and afterwards when the Team collects and analyzes the data. All testing of the Mission will be supervised by Chris Galena and Garrett Bell.

II.h.i Vacuum Chamber Test

The Mission will be changing pressures from $1.013 \times 10^5$ Pa to approximately $1.120 \times 10^3$ Pa during the flight. The Team will need to contact Chris Koehler in order to occupy this space for testing. This test will be conducted in the Aerospace wing of the Engineering Center at the University of Colorado at Boulder, using JANA, a vacuum chamber capable of producing temperatures between $100^\circ$ Celsius to $-180^\circ$ Celsius inside an 18 inch by 30 inch bell jar, to test how the Mission will react to pressure changes. If there are any difficulties after this test, the Team will make any modifications necessary, to prevent damage to the Mission. The design of the Mission will be improved using the results of these tests and the Team will repeat the test as needed.

II.h.ii Whip Test

In order to prepare for the high-velocity and G-forces the Mission will experience when the balloon bursts as well as other moments during the flight, the Team will attach the Mission to a flight cord and a team member will whip it around their head. The Team will add the necessary mass for this test in order to replicate the mass of the payload without damaging the hardware and exert rotational force on the Mission for one minute. The Team will then use the whip test once more with all internal structures intact. The design of the Mission will be improved using the results of these tests and the Team will repeat the test as needed.

II.h.iii Drop Test

It is important the Team be sure that the internal structures survive landing in order to collect and analyze the data. The Mission will be dropped from a height of approximately 10 meters onto different surfaces in order to guarantee all of the internal structures stay intact and undamaged. The Team will add the necessary mass for this test in order to replicate the mass of the payload without damaging the hardware. The Team will repeat the drop test but with the internal structures intact if the prior test goes as planned. The design of the Mission will be improved using the results of these tests and the Team will repeat the test as needed.

II.h.iv Ambient Sound Test

In order to measure the sounds accurately and with precision, the Team will need to ensure the ambient noise during the flight will not interfere with the Mission’s collection of data. To simulate the expected properties of ambient noise, the Team will place the Mission outside of a vehicle traveling the expected ascent and descent velocities and collect data using the sound sensor. This data will then be used to determine an appropriate emission frequency and amplitude from the speaker. The design of the Mission will be improved using the results of this test and the Team will repeat the test as needed.

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II.h.v Temperature Test

When in flight, temperatures as low as -80°C will occur which can impair the functionality of electronic equipment. The Mission will be exposed to dry ice for two hours in a beer cooler while the internal structures are intact and running, in order to test insulation of the Mission. Any functions that get destroyed due to the temperature will result in revisions to the design, and the Team then will repeat the cooling test. The Team members handling the dry ice will be sure to wear gloves while the other members are at a distance in order to ensure everyone’s safety.

II.h.vi Internal Structure Test

The camera, both Arduino Unos, both sensors, speaker, and battery will all be individually tested and analyzed. The Team will make sure each works properly and collects data accurately. It is highly important that the Arduino Unos, the speaker and the sound sensor all run correctly considering these are what will collect the data for the Team to analyze. If there are any uncertainties the internal structuring won’t collect the data precisely, modifications will be made until the Team is confident in the Mission’s flight.

II.h.vii Mission Simulation Test

The Team will use this test to ensure everything compiled in the Mission will work cohesively together. Once all of the previous tests are completed and the Team feels confident in the Mission, the Team will test that everything works well together and to confirm there are no last-minute errors or damages that need fixing before launch.

II.h.viii Safety

The Team is aware the dangers of working with materials such as soldering irons, saws, dry ice, drills, and other machines that are required to build and test the Mission. Considering these factors, the Team will be diligent to ensuring every member’s safety utilizing the proper safety equipment, work in sub teams when dealing with machinery, handle circuits only when they are safe to do so, and exercise extreme caution when handling potentially dangerous materials. The Team will test the Mission in areas removed from the general population to ensure the safety of all. Furthermore, the Mission will be launched in an area determined to be safe by the course instructor and in accordance with all Federal Aviation Administration policies and guidelines.

Section III. Management and Cost Overview

III.a Schedule

The Team will be meeting on Mondays from seven to nine pm and on Sundays from two to four pm; subcommittees on the Team will be meeting at least once per week depending on individual schedule alignment, but all team members are encouraged to participate as much as possible. With regulated and diligently executed meeting times, the Team will be able to finish the Mission on schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Objective/Event</th>
<th>System Category</th>
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</thead>
<tbody>
<tr>
<td>Feb 12-18</td>
<td>HW 06 Due; Authority to proceed granted; Purchase required parts. Complete initial design</td>
<td>Budget Project Managers Budget Structure</td>
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<tr>
<td>Feb 19-25</td>
<td>HW 07 due; HW 08 due; Acquire materials.</td>
<td>Thermal Systems Structure</td>
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</tbody>
</table>
### III.b Budget, Weight, and Acquisition

The Team will be ensuring it does not exceed budget with diligent monitoring and constant updates by the Team’s financial coordinator, Grant Hupp. The below table indexes the cost, weight, and supplier of the Team’s necessary materials.

<table>
<thead>
<tr>
<th>Necessary Supplies</th>
<th>Source</th>
<th>Quantity</th>
<th>Mass* (g)</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Sound detector</td>
<td>Sparkfun</td>
<td>2</td>
<td>10.7</td>
<td>$21.90</td>
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<tr>
<td>Mini Speaker</td>
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<tr>
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<tr>
<td>Electrical Tape</td>
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<td>$10.00</td>
</tr>
</tbody>
</table>
### III. Team Member Biographies

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number/Email</th>
<th>State</th>
<th>Major</th>
<th>Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garrett Bell</td>
<td>(405) 227-5500 <a href="mailto:gabe0760@colorado.edu">gabe0760@colorado.edu</a></td>
<td>OK</td>
<td>Aerospace Engineering</td>
<td>Testing, Thermal, &amp; Science</td>
</tr>
<tr>
<td>Kelly Crombie</td>
<td>(630) 577-7412 <a href="mailto:kecr9321@colorado.edu">kecr9321@colorado.edu</a></td>
<td>IL</td>
<td>Aerospace Engineering</td>
<td>Software, Power &amp; Production</td>
</tr>
<tr>
<td>Chris Galena</td>
<td>(630) 486-8540 <a href="mailto:chga6763@colorado.edu">chga6763@colorado.edu</a></td>
<td>IL</td>
<td>Aerospace Engineering</td>
<td>Testing, Structures, &amp; Systems</td>
</tr>
<tr>
<td>Grant Hupp</td>
<td>(224) 374-6116 <a href="mailto:grhu8202@colorado.edu">grhu8202@colorado.edu</a></td>
<td>IL</td>
<td>Aerospace Engineering</td>
<td>Finance, Thermal &amp; Systems</td>
</tr>
<tr>
<td>Cyara Ochart</td>
<td>(719) 551-9073 <a href="mailto:cyoc1481@colorado.edu">cyoc1481@colorado.edu</a></td>
<td>CO</td>
<td>Astronomy</td>
<td>Structures &amp; C&amp;DH</td>
</tr>
<tr>
<td>James Roberts</td>
<td>(504) 224-1522 <a href="mailto:jaro3678@colorado.edu">jaro3678@colorado.edu</a></td>
<td>LA/CO</td>
<td>Astronomy</td>
<td>Management, Power &amp; Science</td>
</tr>
<tr>
<td>Alexis Wall</td>
<td>(303) 656-8561 <a href="mailto:alwa9024@colorado.edu">alwa9024@colorado.edu</a></td>
<td>CO</td>
<td>Aerospace Engineering</td>
<td>Management, Software, &amp; C&amp;DH</td>
</tr>
</tbody>
</table>

*Masses of resources not to be flown in the Mission marked as N/A

Commented [LC24]: Put “provided” or N/A here instead of $0
**III.d Organization**

The Team has been broken up into 10 subcategories in order to organize who has what job. The organizational chart also helps to schedule when the team members can meet in each subcategory to work on that specific area of the Mission. The project co-managers are Alexis Wall and James Roberts.

Commented [LC25]: Ok. Be sure to elaborate on these in the Design Doc.