Team AWLSEM
Alex Mulvaney
Will Butler
Logan Thompson
Sheridan Godfrey
Erika Polhamus
Megan Keogh

Project Endurance Proposal
September 21, 2015
Gateway to Space
1.0 Overview and Mission Statement

1.1 Mission Statement

The overall mission of Endurance is to collect samples of bacteria at an altitude of 27-30 km by utilizing a near spacecraft. The bacteria will be collected within two petri dishes and an oxygen sensor connected to an Arduino will log oxygen levels relative to altitude. The two petri dishes will then be cultured upon retrieval in different environmental conditions and will be carefully studied to examine which bacteria endurance collected.

1.2 Mission Overview

The idea for this mission inspired by past BalloonSat experiments along with prior knowledge of extremophiles. Of particular interest, were the tardigrade organisms found on the exterior of the International Space Station. It is believed that these organisms were on a spacecraft and survived the ascent into space. Water Bears, as the organisms are most commonly referred to as, are able to survive in the sub-zero, oxygen free, vacuum of space (Brennand, 2011). As a team of aerospace engineers, this sparked interest among the members of Team AWLSEM.

After further research, it was discovered that there are many extremophiles that live in similar conditions to that of the Earth’s stratosphere. For example, scientists at the Georgia Institute of Technology discovered that the jet stream carries approximately 314 different bacterial families in the wind. Of those 314 families, 17 types of bacteria were found in the upper troposphere (Wade, 2013).

Furthermore, there are algae and protozoans that survive in sea ice, which can freeze down to approximately -20°C (Thomas, Dieckmann, 2002). However, this is much warmer in comparison to the -80°C temperatures that the balloon satellite will endure on its ascent to near space. While there would be an issue of proving that bacteria exists in -80°C, Endurance would rather collect the bacteria in the stratosphere which ranges from -45°C to -55°C.

Using the data of an experiment conducted by the Indian Space Research Organization (ISRO), it was shown that the bacteria *Bacillus aryabhata* is existent and thriving at an altitude of 41 km, proving that the stratosphere is an sustainable environment to certain bacteria in the bacillus genus (Discovery, 2009). Understanding this data, Endurance’s goal is to collect bacteria in the bacillus genus including: *Bacillus altitudinis* and *Bacillus stratosphericus* (Nguyen, 2012); and to collect microorganisms such as tardigrades. Mission expectations are that at higher altitudes, life will exist in lower quantities. Air samples will be taken from ground level altitude (approximately 6000 ft. above sea level) and in the stratosphere (approximately 80,000 ft. above sea level). After retrieval, one of the high altitude samples will be incubated at ground level conditions and one will be incubated at high altitude conditions. These samples will then be compared to the control petri dish and the ground sample. This experiment will be explained in length in the technical section of the proposal.
2.0 Technical Overview:
2.1 How:

Team Endurance will order the parts necessitated by this proposal upon approval. Table:Project Expenses [below] outlines where they will be purchased from: online from SparkFun.com, Amazon.com, RobotShop.com; or purchased locally when possible.

The parts will be inspected for quality visually, by compatibility with the Arduino Uno, in hot boxes, with dry ice, in pressure chambers, high/low oxygen environments, and through shock tests.

The parts will be integrated into the structure by the whole team during the fabrication phase according to the schematics and diagrams outlined here in the proposal.

Once each system is constructed it will be subjected to the appropriate testing before being integrated together with other systems. The team will quality control as each system is integrated together as needed. The team will also perform extensive testing of Endurance as a whole. The testing procedures are outlined in the [Testing] section below.

Designs and/or processes may be required to be modified and improved as needed according to circumstances and in process feedback.

2.2 Structure:

Endurance will have the main design features of the structure will be 1) It is a cubic shape 2) An air scoop built into the roof 3) The external components and 4) Internal support.

The shape of the structure is a cube with sides of 30cm wide by 30cm long by 17.5cm high. It will be constructed out of foam core insulating material and supported by internal structure.

The air collection apparatus will be built into the roof on the mission side of Endurance. Its shape will be that of a funnel and a depth of 8.5cm. This system will feed into the sample collection area through rigid directional air chambers (tubes).

External to the structure will be the interfaces. These will include power switches for each of the systems, an opening for the secondary experiment (camera slot), and the air scoop.

On the inside of Endurance will be supports for the internal systems including electrical, battery, control and payload. Endurance will also contain a partition dividing the internal chamber into two parts. The first chamber will be fully sealed from the external environment to protect the majority of the onboard systems, some of which are fragile or sensitive to temperature. The second internal chamber will contain the sample collection materials (petri dishes).
Project Endurance

dishes) and air delivery systems. This second chamber will be partially exposed to the outside environment by the air collection systems but still temperature-controlled through use of heating pads under the sample collectors.

2.3.1 Experiment (Primary):
Endurance will house three sterilized, agar filled petri dishes, one control dish and two test dishes which will be opened in near space (30km) by using a servo operated arm and velcro [figure 2] to open the lids of the dishes at a designated pressure. The air pressure at 28 km (about the middle of the stratosphere) is about 9.5 torr, or 1,266.5625 Pascals. This, would be converted to 0.18369936 psi at this exact altitude. When the onboard pressure sensor detects this condition, the Arduino will engage the servo. This will expose the sample collection material (agar) to the collection environment (outside) and collection will begin. After 10 minutes or detection of burst (whichever occurs first) the Arduino will signal the servo to close the collection apparatus and the collection phase will be complete.

At this point the primary payload will enter its passive phase. This phase consists only of regulating the temperature of the collection materials to a minimum of 10deg Celsius until touchdown.

2.3.2 Experiment (Secondary):
The secondary experiment of Endurance will be to capture images of earth from the unique perspective of 100,000 feet altitude. This will be accomplished by the camera system taking photographs through the camera window built into the outside of Endurance. The camera system’s functioning is detailed in the block diagram. The camera will be programmed to take one picture a minute and store them on the onboard SD card until it reaches an altitude of 15km.

2.4 Data Collection:
In this mission two types of data will be collected, the bacteria in the petri dishes and the information from the temperature, oxygen, pressure, humidity and acceleration sensors. The data that will be collected in the petri dishes will be bacteria and microbial life that will get caught in the agar when the lids are opened from the Servos. After recovery and incubation each petri dish will be carefully examined to see what bacterial life has been caught. The three petri dishes will be compared to the control dish that was kept on Earth to define the related bacteria found in both environments (that of Earth’s surface and of the stratosphere). Then, the two petri dishes that were opened in the stratosphere will be incubated in different environments to test which, if any, survive. One of these dishes will be incubated in an environment close to that of the

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stratosphere, such as in a cold, limited oxygenated habitat, while the other will be incubated in an Earthlike environment, in room temperature and a normal atmosphere. After incubation in a growth medium the samples will be studied under a microscope to view and classify the bacteria collected. The data from the oxygen sensor that has been collected and stored by the second Arduino will then be compared against the species of bacteria that are found in the petri dish. This will determine what oxygen levels the bacteria collected need to survive.

After recovery the SD card will be plugged into a computer to retrieve the data from the flight. Once every 30 seconds the Arduino will keep the data from the temperature, humidity, oxygen, pressure, and acceleration sensors. The camera will be taking one photo a minute until the 28 to 30 km point and then will take five photos a minute. The video taken will be 2 minutes after launch then one minute later for two minutes and once for 5 minutes at 20 kilometers.

2.4 Functional Block Diagram:

![Block Diagram Image]

2.5 Safety Information:

A main priority while building and testing the BalloonSat is safety. If not careful, there is potential for serious injury. All aspects of building and testing the balloon satellite will be carried out with great caution. There are a few specific safety precautions that will be taken to ensure that no team member gets hurt. When soldering irons are in use, safety glasses must be worn at all times. Full attention to the soldering will be mandatory, as failure to comply may result in burns. During the whip test, team members not actively participating will be required to stand away from the satellite in case of rope failure.

One of the most dangerous aspects of the BalloonSat production will be the cold test using dry ice. Before handling, each team member will read the Occupational Safety and Health Administration “Quick Facts” article on dry ice (Gloves and safety goggles will be used at all times during the cold test. If all of the safety guidelines are met, there will be minimal risk to injury during the building and testing of Endurance.

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2.6 Structural Testing:

2.6.1 Whip Test: During the BalloonSat’s descent, the structure will endure intense shaking and high wind speeds. To make sure the structure will not collapse in this part of the flight, a whip test will be conducted. The satellite will be loaded with mass simulants that weigh the same as the payload. It will then be attached to a string and quickly moved around the air. When the satellite is stable, it will be able to be whipped around at high speeds without movement of the internal hardware or damage to external structure. This test will be conducted in an open area as to not damage university property.

2.6.2 Drop Test: The satellite will experience a high-impact fall at the end of its descent. Even with the parachute, the satellite will hit the ground with blunt force. To make sure the structure can withstand the impact, a drop test will be conducted. The satellite will be loaded with weights similar to the weight of the payload and dropped from approximately ten meters. After being dropped, the structure will be assessed and adjusted based on any damage caused by the fall.

2.6.3 Stair Test: The purpose of the stair test is to ensure that the satellite is strong enough to withstand windy conditions and impact of landing. Endurance will be loaded with weights similar to the payload and dropped down a flight of stairs. The structure will be assessed and repaired based on any damages.

2.6.4 Cold Test: Endurance will be exposed to external temperatures up to \(-80^\circ\)C during flight. Extreme cold can cause hardware to malfunction. To prevent this, a cold test will be conducted. The BalloonSat will be placed in a cooler with dry ice and left to run all hardware and sensors. This test will ensure that the internal temperature of the BalloonSat is warm enough to keep all hardware running and warm enough to keep the agar from freezing.

2.7 Non Structural Testing:

2.7.1 Camera Testing: The camera will be placed inside the satellite during the cold test. It will be programmed to take pictures every 20 seconds throughout the test to ensure that it will work even at the coldest temperatures.

2.7.2 Sensor- Testing: The success of the mission is partly dependent on the data retrieved while in flight. To ensure that all of the sensors work, they will all be run during the cold test. The sensors must be able to read data and transfer the data successfully to the Arduino.

2.7.3 Full-Functioning Test: The last test before launch is the full-functioning test. All of the systems within the BalloonSat be left to run for 3 hours. This is to make sure that all of the equipment can endure the entire length of the mission.

3.0 Management:

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3.1 Schedule:
The schedule calls for accomplishing the following table of milestones:

- **Friday 9/25:** Authority to Proceed
- **Saturday 9/26:** Design Finalized & Parts Ordered
- **Tuesday 9/31:** Team Meeting (7-9pm)
- **Thursday 10/3:** Team Meeting (7-9pm)
- **Sunday 10/6:** Parts Arrive
- **Tuesday 10/8:** Preliminary Design Review and Team Meeting (7-9pm)
- **Tuesday 10/13:** Team Meeting (7-9pm)
- **Thursday 10/15:** Team Meeting (7-9pm)
- **Monday 10/19:** Subsystems Complete
- **Tuesday 10/20:** DD Rev A/B Complete
- **Thursday 10/22:** Team Meeting (7-9pm)
- **Monday 10/19:** Friday 10/23: Subsystem Testing (Camera, Sensor Calibration, Thermal, Power, Science)
- **Friday 10/23:** Structure Complete
- **Tuesday 10/27:** Assembled Sat Ready for Testing & Team Meeting (7-9pm)
- **Monday 10/26:**
- **Thursday 10/29:** Structural Tests (Whip, Impact) & Full System Cold Test
- **Tuesday 10/29:** In Class Mission Simulation Test & Team Meeting (7-9pm)
- **Tuesday 11/3:** Launch Readiness Review Complete & Team Meeting (7-9pm)
- **Thursday 11/5:** Team Meeting (7-9pm)
- **Friday 11/6:** DD Rev C Complete & Team Meeting (7-9pm)
- **Saturday 11/7:** **LAUNCH!**
- **Tuesday 11/10:** Team Meeting (7-9pm)
- **Thursday 11/12:** Post-Launch Presentation Complete & Team Meeting (7-9pm)
- **Tuesday 11/17:** Team Meeting (7-9pm)
- **Monday 11/19:** Team Meeting (7-9pm)
- **Saturday 12/5:** ITLL Design Expo & Team Video Complete & DD Rev D Draft 1 Complete
- **Tuesday 12/15:** Final Presentation Complete & DD Draft D Final

3.2 Budgeting:
Team AWLSEM has a budget constraint of 180$. Parts have been sourced with this in mind from both online and locally. Some materials are available through the ITLL at CU Boulder for free for student use on this project. The total estimated cost to date is the project is total cost of $158.33.

3.2.1 Table- Project Expenses:

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<thead>
<tr>
<th>Item</th>
<th>Cost (including)</th>
<th>Weight</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team AWLSEM</td>
<td></td>
<td></td>
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</table>
### Project Endurance

#### Team AWLSEM

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Weight</th>
<th>Supplier</th>
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</thead>
<tbody>
<tr>
<td>Oxygen Sensor</td>
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<tr>
<td>Servo Motor</td>
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<td>1 inch diameter plastic tubing</td>
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<td>Lowes</td>
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<td>Petri dishes and agar (3)</td>
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<td><strong>Heating Pads (2)</strong></td>
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<td>Sparkfun.com</td>
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<td>Arduino uno + balloon shield (2)</td>
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<td>University of Colorado, Boulder</td>
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<tr>
<td>Micro SD Cards + shield (3)</td>
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<td>University of Colorado, Boulder</td>
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<td>Camera</td>
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<td>4v Lithium Batteries</td>
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<td>Sensors (various)</td>
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<td>Foam-core, Insulation &amp; Structural Elements</td>
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<tr>
<td>Heater</td>
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<td>Batteries (extra)</td>
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**Total Weight:** 858g

**Total cost:** $158.33

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### 3.3 Team Members:

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Job Title</th>
<th>Special Skills</th>
<th>Address</th>
<th>Phone Number</th>
<th>School</th>
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</thead>
</table>
| Alex Mulvaney           | Team Lead/Chief Actuator Fabrication Engineer | - Construction/Mechanical experience  
- C/C++ experience | 1742 Walnut st #5  
Boulder, Colorado 80302 | 729-7996745 | University of Colorado, Boulder |
|                         |                                  | - Make sure team members have the tools to succeed  
- Design & fabricate lifting arms and motive components of the experiment |
| Megan                   | Budget and Planning Coordinator / Mission | - Basic soldering  
- Basic computer programming  
- Experience with cell | 0110 ANDR  
2510 Kittredge  
Loop Road  
Boulder, CO 80310 | 360-287-3650 | University of Colorado, Boulder |

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3.4 Organization Chart:


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