Mission Overview

**Objectives:** The overall mission of Endurance is to collect samples of bacteria at an altitude of 27-30 km in order to count the colonies that survive descent and incubation.

**Why?**
- to understand and retrieve data about the environment that the bacteria and microorganisms were collected in
- information can be applied to extreme environments on Earth and environments on other planets in the solar system
**Phase 01: Launch**
- Endurance will house two sterilized, agar-filled petri dishes

**Phase 02: Flight**
- The two test dishes will be opened at a designated pressure by using the Arduino to engage the servo and lift the lids by use of velcro
- During this process the camera system will be taking pictures every 10 seconds and saving them to the SD card

**Phase 03: Burst**
- After the agar has been exposed for 10 minutes the Arduino will signal the servo to close the lids of the test dishes
- Information from the temperature, oxygen, pressure, humidity and acceleration sensors will be collected as well using the Arduino

**Phase 04: Descent**
- Endurance will then regulate the temperature of the collection materials to a minimum of 10 degrees Celsius until touchdown

**Phase 05: Landing**
- Retrieval of Endurance will be followed by incubating the petri dishes as well as reviewing the data from all the sensors and camera
Accuracy of Flight to ConOps

- **Phase 1 successful**: BalloonSat launched
- **Phase 2 unsuccessful**: GoPro took pictures at correct times, but servo arm didn’t open
- **Phase 3 unsuccessful**: external temperature sensor failed
- **Phase 4 unsuccessful**: inconclusive temperature readings
- **Phase 5 successful**: BalloonSat was retrieved, data analysed, pictures were taken
Flight Data

- Burst occurred at 95,282 feet
- GoPro took 147 photos in total
- SD card had readings from all sensors
- Petri dish may not have opened since there was not a hole in the paper
- Lid of petri dish was disconnected (most likely from impact) during retrieval
Design: Drawing/Models

Proposed Design

Final Design
Flown Design

- Cut out more of funnel to reduce weight
- Cut out rectangles on sides to reduce weight
- Heating pad not used
Design: FBD
Predicted Data
Results and analysis
Flight Datum

- Failure of external temperature sensor
- This cascaded and gave data spikes in the rest of the sensors (shown)

- Internal temperature sensor and humidity sensor
Flight Datum

- X and Z component of the g-forces data. They were affected by faulty external temperature sensor.

- Pressure reading labeled with launch, burst, and landing.
Flight Datum

- This is the data from the oxygen sensor, marked with significant events. Data was as expected.
Failure Analysis: Hardware

- Three main hardware failures
- Servo motor did not fully open (partially coding)
- Servo motor disconnected from wall mount on impact
- External temperature sensor failed due to faulty solder joint

Post-Flight Fixed

- RH (%)
- Pres (psi)
- XG (g)
- 2G (g)
- Temp1 (°C)
- Temp2 (°C)

Internal and External Temperature Sensors: Post Launch

Room temp (120deg rot)
Freezer temp (45deg rot)
Coding Failure

- Due to unanticipated voltage spikes the ‘if’ conditions of the code were tripped early and at the same time.
- This completed the single run motor cycle far earlier than anticipated.
- This is shown at right, the data spike and the timing of the next cycle, with an extra 250ms for opening and 250ms for closing.
Biological Failure

- Servo motor broke off of wall exposing the agar plate to ground environment
  - Servo velcroed, hot glued and braced against wall with wire
  - Plate secured to box with hot glue
    - Fixed by velcroing and hot gluing plate to stationary servo arm and structure of box
- Tested by dropping box from 2nd floor of DLC and checking to see if plate and servo motor were secured
  - Everything survived drop
Conclusion

● About 60% failure
  ○ external temperature sensor failed (soldered incorrectly)
  ○ petri dish lid fell off base upon landing (contaminated)

● What went correctly
  ○ oxygen sensor and pressure sensor were very accurate to as predicted
  ○ Go-Pro was successful; took 147 photos
  ○ Humidity and accelerometer had the same accurate trends as predicted
Lessons Learned

Take data noise into account when writing code

Do not use rocks as weights during structural testing

Account for structural replication when using materials

Test all vital components thoroughly before flight

Plan dimensions more carefully
Ready to Fly

- Clear SD cards (Arduino and camera)
- Remove and visually inspect all electronic components
- Store all electronic components in dry, secure area
- Seal structure of BalloonSat with tape to prevent damage
- Return components to Prof. Koehler
- Replace flight batteries for refligh
Acknowledgements

Thank you to Dr. Noah Fierer, Dr. Paul Carini, Tim May, Matt Rhode and Edge of Space Sciences for all your help. Team AWLSEM would not be the same without you.
Appendix: Message to Next Semester

- Be exact on calculations for weight and size of the satellite to prevent last-minute design changes
- Filters are much more efficient and lighter than petri dishes
- Give ample times to run cold test
- Do not put the external temperature sensor in backwards
Appendix: RFP Compliance

147 pictures taken with GoPro
Data collected from all sensors and stored to SD card
Collected and incubated bacteria and completed a colony count
Satellite reached altitude of 95,282 ft
Final weight of BalloonSat: 889g
Exterior of *Endurance* had working LED lights, American flag and retrieval number
## Appendix: Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Weight</th>
<th>Supplier</th>
<th>Part Number</th>
</tr>
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<tbody>
<tr>
<td>Oxygen Sensor</td>
<td>$70.95</td>
<td>75g</td>
<td>Robotshop.com</td>
<td>10120001</td>
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<tr>
<td>Servo (motor, arm)</td>
<td>$35.81</td>
<td>44g</td>
<td>Sparkfun.com</td>
<td>ROB-09347</td>
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<tr>
<td>1.5 inch Diameter plastic tubing</td>
<td>$1.99**</td>
<td>N/A</td>
<td>McGuckin Hardware</td>
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<tr>
<td>Petri dishes and agar (2 packs)</td>
<td>$19.99</td>
<td>N/A</td>
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<tr>
<td>Hearing pads (2)</td>
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<td>COM-11266</td>
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<tr>
<td>Arduino Uno and baloon shield</td>
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<tr>
<td>Micro SD Card and shield (3)</td>
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<td>3.8g</td>
<td>University of Colorado, Boulder</td>
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<tr>
<td>GoPro</td>
<td>Previously-Owned</td>
<td>7g</td>
<td>Megan Keogh</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Total Cost: $215.55  
Cost from students: $60  
Total Planned Weight: 853.6g  
Final Flight Weight: 889g