Team Nacho Libre

Written by:
Ryan Stewart, Howie Ritter, Joel Marquez, Luz Ibarra, Marisa Exnicious, Luke Beasley

March 3rd, 2016
Rev A/B

Revision Log
<table>
<thead>
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<th>Revision</th>
<th>Description</th>
<th>Date</th>
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<tbody>
<tr>
<td>C</td>
<td>Critical Design Review</td>
<td>April 7, 2016</td>
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</tbody>
</table>

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1.0 Mission Overview

The objective of Project S.C.I.E.N.C.E. is to design, build, and launch a BalloonSat for the ASEN 1400 Gateway to Space class that will gather required sets of atmospheric data and capture atmospheric microbes at different altitudes and measure the UV (ultraviolet) radiation content at the same time. Insight into how life survives in the harsh environments of near space could be used to develop new technologies for future space missions, or perhaps in the medical field as inspiration for new advancements in the study of genetics.

Microbes, short for microorganisms, include any living thing that is too miniscule to see with the naked eye. These range from bacteria and protozoa to viruses and fungi; all things common to the environments found on Earth. However, recent studies have shown that these organisms also reside in Earth’s atmosphere. Russian astronauts discovered some of these organisms, a form of microscopic invertebrate called tardigrades, on the exterior of the ISS\(^1\). Moreover, in 2013, researchers from the Georgia Institute of Technology in Atlanta gathered data that showed that some of these organisms lived in the upper atmosphere as well. Over 300 separate families of bacteria were cataloged by the scientists, who flew their mission at an altitude of 10 km (troposphere) above the Caribbean, continental U.S., and the coast of California\(^2\). While the exact types and natures of these organisms were difficult to infer, it is still of note that they were able to adapt and survive in space-like conditions, such as increased direct contact with ultraviolet radiation from the sun.

UV radiation is energy emitted from the sun that propagates through space with an average wavelength between 200 nanometers and 400 nanometers. Its short wavelength is indicative of its highly energetic nature, which is known for causing sunburns and skin cancer in the human species. UV radiation exists in three forms: UV-A, the most common, UV-B, known for its carcinogenic properties, and UV-C, which is utilized for its disinfecting characteristics. While UV-A rays are more common, they do not permeate or alter DNA, whereas UV-B rays can distort certain proteins in the genome and harm the cells.\(^3\)

Team Nacho Libre will launch Project S.C.I.E.N.C.E. aboard a weather balloon that will reach an altitude of 30 kilometers. At elevations of 10 and 20 kilometers, covers will be opened on either side of the BalloonSat to allow atmospheric microbes to be captured in petri dishes mounted on the inside of the instrument. A UV sensor will catalog radiation values for the entire journey, the data from which will be analyzed on the ground while the captured microbes are cultured and compared to a control dish left on the ground.

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The data that Project S.C.I.E.N.C.E. procures from this mission could be used to study how organisms can physically adapt to environments with higher radiation levels. Team Nacho Libre expects to see the number of these atmospheric microbes wane as higher altitudes are reached due to decreased protection from UV-B radiation above the ozone layer. It is the microbes found at these higher elevations that will be studied closely. The data could also be used to design more effective hardware for upcoming human space missions, such as ORION, where astronauts will be subjected to high levels of both UV-B radiation and cosmic rays.

2.0 Requirements Flow Down

Project S.C.I.E.N.C.E. will involve the opening of two separate petri dishes at two different altitudes, in order to collect two different sets of microbes, while one dish is left unopened as a negative control. Team Nacho Libre plans to gather these samples at two different heights, 10 km and 20 km, while a UV sensor collects the radiation values during the entirety of the journey. The data from this experiment will offer insight into what sorts of organisms are able to survive in harsh, space-like environments, and how later spaceflights can be adapted to simulate the survival mechanisms of these organisms.

Level 0 Requirements

| Number | Requirement                                                                 | Source         |
|--------|-----------------------------------------------------------------------------|----------------|              |
| 0.1    | Project S.C.I.E.N.C.E. shall comply with all requirements set forth in the Request for Proposal from ASEN 1400. | Mission Statement |              |
| 0.2    | Team Nacho Libre shall gather data from interior and exterior temperature sensors, a humidity sensor, an acceleration sensor, and two pressure sensors. | Mission Statement |              |
| 0.3    | Team Nacho Libre shall gather ultraviolet radiation data for the duration of the flight using a UV sensor. | Mission Statement |              |
| 0.4    | Team Nacho Libre shall collect biological samples at two different altitudes and culture them post-launch. | Mission Statement |              |
| 0.5    | Team Nacho Libre shall compare UV radiation data to collected microbial life to find and plot a correlation. | Mission Statement |              |

3.0 Design

3.1 General Overview

To achieve its mission requirements, Project S.C.I.E.N.C.E. will be sent up with two separate compartments along the inside walls of the satellite. These chambers will hold two petri dishes coated with agar, completely sealed prior to launch to preserve sterility. These compartments will be padded and have doors that will be opened, along with the petri dish lid, by servos within the BalloonSat. At approximately 10 km, the first petri dish will be opened by the first Arduino. To achieve this, the Arduino will be receiving data from a second pressure...
sensor, which at 10 km will read approximately 26,500 Pascals of pressure. The Arduino will read this data, and will command one of the two servos to operate and open one of the doors. Once the box reaches 11 km in altitude, a pressure of approximately 22,632.06 Pascals, the second Arduino will prompt the servo to close the door, and will be sealed by a 0.3175 cm rubber tubing. This process will be repeated with the second servo at an altitude of 20 km, or approximately 5,470 Pascals, in order to sample the atmosphere for microbes in different conditions. Upon landing, the petri dish will be easily removed from its encasement simply by pulling it from its velcro anchors on the box. The box will have two methods of confirmation for the opening of the doors: a physical one, where the doors will use the head of a pin to mark the inside of the box as they open, and a non-physical one, where the Arduino will use a counter variable to record whenever the Servos go through any rotation during flight.

The first Arduino will be connected to the environmental sensors and will be powered by a 9 volt lithium battery. During the flight, these sensors will relay the information they gather to the Arduino, which will save the data to a 2GB SD card. The second Arduino will be connected to a second pressure sensor, an ML8511 UV sensor, and the servo system, which takes data relayed by the second pressure sensor and signals each servo to open and close at their respective altitudes. Both the UV sensor data and the additional pressure sensor data will be stored on a 2GB SD card connected to this Arduino.

**Deployment Design**

In order to deploy the petri dishes correctly, Team Nacho Libre plans to utilize a two-way, servo-operated mechanism that will open and close a cover on the housing of the petri dish (see Figure 2). Connected to the second Arduino will be two Generic High-Torque Servos purchased from SparkFun. Each servo requires a range of 4.8 to 6.0 volts, which will be covered by the 5 volts provided by pins on the Arduino. This voltage will come from an external 9 volt lithium battery. Mounted to each of the servos will be a 16 tooth, 32 pitch bevel gear that will mesh with gear racks mounted to two aluminum rods 0.3175 cm in diameter. These rods will be the main driving force for Project S.C.I.E.N.C.E.’s mission. The rods, cut to 8.89 cm in length, will be placed within two 1.27 cm plastic guide tracks, made for sliding doors. The tracks will be 2 cm longer than the rods to accommodate for movement, and the back ends will be sealed to prevent the rods from leaving the tracks.

At the edge of the box, a hole will be cut for the aluminum tubing to pass through. In order to keep the box sealed, rubber tubing that is the same diameter as the aluminum will be hot glued over the hole. On the outside of the box, there will be a door made from the same foam core as the box. It will be attached by a hinge at the opposite end of the opening. The foam core door will have velcro on the inward-facing side, along with two springs. These springs aid in

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keeping the door tightly closed during ascent and descent, and will be tested extensively during both the drop and whip tests to confirm that they keep the petri dishes secure. The velcro on the door will connect to velcro on the lid of the petri dish. When the rod pushes through the opening and makes contact with the door, the door will rotate on the hinge, and the velcro will bring the lid with it. The petri dish and agar will be exposed to the atmosphere for 1 km in order to capture microbial life. After the balloon has risen to 1 km above the opening altitude, the Arduino will take the data from the pressure sensor and signal the servo to reverse and close the opening of the dish.

**Data Analysis and Acquisition**

Post-flight, the SD card from the first Arduino will be connected to a computer using an external card reader. The Arduino will have been coded prior to flight to write the data from each sensor to a readable file. Once the files have been transferred to a computer, Team Nacho Libre will use both Logger Pro and Excel in tandem to create organized, presentable visuals in order to understand trends and better make sense of the data. The data from the UV sensor will be handled similarly using both aforementioned programs. The dishes, including a negative control that never opens, will be removed from their velcro anchors and stored upside down at room temperature for 5 days. This allows for the bacteria to culture, but also prevents condensation from falling off of the lid into the microbial colonies, which could cause them to disperse and render the mission void. Dr. Paul Carini of the University of Colorado at Boulder has graciously agreed to assist Team Nacho Libre with post-launch analysis. After the 5 day culturing period, Dr. Carini will take the dishes to his lab for a colony count and organism identification. The colony counts and other numerical data will be plotted in Logger Pro alongside the UV radiation levels in order to directly show how the level of UV radiation affects the growth of these colonies.

**Programming and Software Design**

The software subsystem team on Team Nacho Libre will code each Arduino to properly receive inputs from the sensors, and either use these inputs to command other mechanisms like the servos, or write the data to a file. The first Arduino will be responsible for storing all the environmental data, while the second will store the UV data and control the servos. The data from the UV sensor will be read using the “analogRead()” command, and the data from the second pressure sensor will be used to initiate the servos. To make the servos rotate 180 degrees and open the doors, the initial position is initialized to zero, and a for loop will be used with the “delay()” command to make sure the servos will only open and close at certain pressure intervals. The code for the servos will make up the bulk of the software required by Team Nacho Libre.

**Structure Design**

The design of the Project S.C.I.E.N.C.E. BalloonSat will be very straightforward in scope. The box will have a standard square base with sides that will be 24 cm in length (see Figure 3). The box will have a vertical height of 13 cm, making it a rectangular prism as opposed to a cube. This will allow us to conserve weight for other parts of the box. The compartments of the petri dishes will collapse into the box a distance of 2.5 cm, and will be 11 cm in length.

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5 https://www.arduino.cc/en/Tutorial/Sweep
These compartments will be made separately and then placed into the box after the sides have been cut to length. The doors will span the length of the doors and then another 2.5 cm on each side to accommodate for the servo mechanism and as an extra layer of protection for the dishes. The compartments will be lined with memory foam that will be sterilized with Dr. Carini’s help. Aluminum tape and hot glue will be used to create the joints and seals between the foam core pieces of the box. The top will remain removable so the data collected can be retrieved afterwards.

**Requirements**

Team Nacho Libre plans to design and launch Project S.C.I.E.N.C.E. while strictly following both the requirements set forth in the Requirements Flow Down detailed above and the specific requirements put forth in the Request for Proposal for the ASEN 1400 class. With respect to the Requirements Flow Down, Requirements 0.1 and 0.2 will be achieved by meticulously meeting all of the requirements within the ASEN 1400 Request for Proposal. These requirements are as follows: Project S.C.I.E.N.C.E. will include an additional experiment and sensor to collect data from the flight, and this data will be analyzed afterwards. The BalloonSat will be returned in working order after landing. Room will be made inside the box for the non-metal tube used for securing the BalloonSat to the nylon string, and it shall be made so that it will not pull through or interfere with the instrumentation of Project S.C.I.E.N.C.E. The inside of the box will not reach temperatures below -10°C and the total weight will not exceed 864 grams. The descent and ascent rates of the flight will be recorded, using the provided accelerometer attached to the first Arduino. The box design will allow for an Arduino Uno plus microSD card, an external temperature sensor that will extend 2.54 cm from the outside of the box, a Canon A3400 IS Digital Camera and its accompanying batteries and SD card (replaced by the GoPro), and an active heating system weighing 36 g with batteries and dimensions of 10x50x50 mm. The heater dimensions will not include the optional 3.9 volt batteries. The BalloonSat frame will be crafted using foam core, which will help keep the weight low while retaining strength. The cost of spare parts will be included in the final budget. The box will have contact information and a US flag applied to its exterior. All units mentioned will be in metric. Team Nacho Libre will be present and punctual for launch day on April 9th, and no one will be injured during preparation or analysis. All hardware will be returned in working order to COSGC, and all parts will be ordered through Chris Koehler’s CU Visa by appointment. Receipts will be kept and turned in within 48 hours of purchase with the team name on the receipt and a copy of the Gateway order form. No living organisms will be flown up on Project S.C.I.E.N.C.E., and the microbes collected will be studied and disposed of ethically and safely. A final report will be created after the balloon lands. External LEDs will be used to signify that everything within the box is running properly. Meticulous wiring practices will be maintained throughout the design process in order to prevent failure. All external switches will be protected with foam core.
Team Nacho Libre will meet the 0.3 requirement by first purchasing a UV radiation sensor from SparkFun. This sensor will then be calibrated and connected to the second Arduino, and will be programmed to collect data throughout the flight. The 0.4 requirement will be met by placing petri dishes within the compartments of the box and exposing them to the atmosphere at different altitudes to allow for microbe collection. They will then be kept in an environment at room temperature for several days to give the microbes time to culture. The 0.5 requirement will be met after all the data has been collected. The colonies in the dishes will be counted and, time depending, identified under the supervision of Dr. Paul Carini. The UV radiation data and these colony counts will be plotted using either Excel or Logger Pro, and these graphs will allow for some correlation between the two data sets to be determined.

3.2 Functional Block Diagram

The following is a functional block diagram that lays out all the individual components used for Project S.C.I.E.N.C.E. and how they will work together to form one cohesive unit to achieve the mission objective.

3.3 Concept of Operations

Team Nacho Libre will begin Project S.C.I.E.N.C.E. by turning on the GoPro and the switches on the outside of the box. The balloon will then launch as the sensors on board begin to record data. At an altitude of 10 km, one of the two Arduinos inside the box will be triggered by the altitude and pressure sensor connected to it and will communicate to the servo to open the first petri dish. That petri dish will be closed at an altitude of 11 km by the Arduino taking information from the pressure sensor and relaying to the servo to reverse and close the door. At
an altitude of 20 km, this process will be repeated with the second petri dish, which will be closed at 21 km. The balloon will rupture at approximately 30 km. The BalloonSat will then descend, and Team Nacho Libre will recover it. Post-launch, Team Nacho Libre will consult with Dr. Paul Carini to culture the microbes collected in the petri dishes. While the samples are being cultured, analysis will be done of the data collected by the required sensors as well as by the UV sensor to draw conclusions about flight conditions as well as habitable conditions as altitude increases.
3.4 Parts
To complete Project S.C.I.E.N.C.E., Team Nacho Libre has assembled a tentative list of parts necessary for building and design, which are laid out extensively in the budget. The box itself will be made out of a foam core structure, which will be provided by the Colorado Space Grant Consortium. Two Arduino Unos will also be used, one for required data and one specifically for the science mission. These will also be provided by Colorado Space Grant Consortium, as will be the parts necessary for the heater, the switches, the environmental sensors, LEDs, SD cards and shields, and the flight batteries. Team Nacho Libre will replace the provided Canon camera with a GoPro at Chris Koehler’s discretion, in order to conserve weight. To construct the mechanism, Team Nacho Libre will purchase two Standard Generic High Torque Servos (P/N S5106B) from SparkFun. The team will also purchase a UV sensor and an additional pressure sensor from SparkFun. The door tracks for the mechanism will be purchased from Woodworker Express, and the door hinges from Hardware Source. The bevel gears for the servos and the gear racks for the rods will be purchased from ServoCity. The aluminum rod will be purchased from Home Depot, and the memory foam inserts for the dishes will be cut from a pillow purchased from Baby Goes to Town. The petri dishes, for tests and flight, will be purchased alongside extra batteries from Amazon. Any other parts or expenses will be dealt with on a case-by-case basis, specifically when dealing with spare parts and returns.

4.0 Management
Ryan Stewart is team Nacho Libre’s project manager and he will be in charge of overseeing the development of the mission. Project S.C.I.E.N.C.E. is determined to promote an inclusive, team-oriented environment while also allowing for individual creativity. To achieve their mission, Team Nacho Libre has divided into separate subsystem teams, each consisting of two main members and an extra support member. The teams include science, power, mechanics, control and data handling, software, and structures. The chart below shows which team members are part of each subsystem team.
### 4.1 Schedule

Team Nacho Libre plans to meet three times every week for two hours on Tuesdays, Thursdays, and Sundays. All homeworks will be started in the team meeting after they have been assigned. Emergency meetings will called whenever necessary, as decided by the project manager.

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<tr>
<th>Date</th>
<th>Activities</th>
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</thead>
<tbody>
<tr>
<td><strong>Friday January 22, 2016</strong></td>
<td>• First meeting at Beau Jo’s, introductions and HW 03</td>
</tr>
</tbody>
</table>
| **Sunday January 24, 2016 - Saturday January 30, 2016** | • Finalize secondary mission  
• CoDR presentation/practice  
• Begin proposal |
| **Sunday January 31, 2016 - Saturday February 6, 2016** | • Final practice for CoDR  
• Finalize Section I of proposal  
• Record CoDR for Chris and upload to YouTube (Due: Feb 3)  
• Proposal Section II editing  
• Finish HW 04  
• 3D modeling for Structures team |
| **Sunday February 7, 2016 - Saturday February 13, 2016** | • Finish and revise proposal  
• Proposal due February 8th (8 AM)  
• No meetings (APPM exams) |
| **Sunday February 14, 2016 - Saturday February 18, 2016** | • Begin prototype construction  
• Begin pseudocode for Arduino 2 (Joel/Marisa)  
• HW 08 due  
• Prototype finalized, analyzed, edited as necessary  
• Begin DD rev A/B |
| **Sunday February 21, 2016 - Saturday February 27, 2016** | • Finalize pseudocode for both Arduinos, begin PDR powerpoint  
• Create parts list for final box design  
• Order parts, update budget  
• Foam core assembly for box structure and compartments  
• HW 7 due, finish PDR powerpoint  
• Finalize DD rev A/B |
| **Sunday February 28, 2016 - Saturday March 5, 2016** | • Record PDR presentation, inventory parts  
• PDR presentation due, begin final coding for Arduino 2  
• Budget audit, servo system assembly  
• Revise code as necessary |
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| Sunday March 6, 2016 - Saturday March 12, 2016 | - Data testing for both Arduinos  
- Finish box structure, weigh and measure  
- DD rev A/B due  
- Complete drop/stair test (ITLL), collect data  
- Complete whip test (Koebel field), collect data  
- Revise box as necessary based on tests  
- Mount Arduino 1 & 2, heater, and camera to box  
- Cold test final box with components running |
| Sunday March 13, 2016 - Saturday March 19, 2016 | - Study cold test data, record for DD  
- Mechanism Soft Test  
- Edit design and code as necessary  
- Mount servo assembly to box  
- Mechanism Hard Test  
- Begin DD rev C |
| Monday March 21 - Friday March 25, 2016       | - Spring Break, no meetings (community service and HW 09)  
- DD rev C work |
| Sunday March 27, 2016 - Saturday April 2, 2016 | - HW 9 due  
- Administrative meeting (shortened)  
- LRR powerpoint  
- Budget audit  
- Practice LRR and edit powerpoint as necessary  
- Altitude test + Mission Sim test (Flagstaff) |
| Sunday April 3, 2016 - Saturday April 9, 2016  | - Finish software and hardware testing and complete integration  
- Complete DD rev C (Due April 7)  
- LRR presentations, no meeting  
- Check for any final imperfections and fix accordingly  
- Turn in and weigh final BalloonSat  
- LAUNCH DAY  
- Start culture/data analysis after landing |
| Sunday April 10, 2016 - Saturday April 16, 2016 | - Use Excel and Logger Pro for analysis of in-flight data from Arduino 1 and 2  
- Consult with Dr. Carini to analyze results  
- Time depending, do culture identification |
• Compare colony numbers to UV data, find correlation
• Edit DD accordingly
• Work on QLPL powerpoint/practice presentation as team
• Begin presentation for Design Expo

Sunday April 17, 2016 - Saturday April 23, 2016

• HW 10
• Begin final presentation Powerpoint
• Complete microorganism identification (if possible/not already completed)
• Finish Design Expo presentation/practice presentation
• Finish final presentation powerpoint/practice presentation
• Complete analysis of data from both Arduinos, label and complete all plots accordingly
• Extra credit video completed
• DESIGN EXPO (8 AM - 1PM)

Sunday April 24, 2016 - Monday May 2, 2016

• Final presentations
• Revise and edit final DD
• Return all hardware to Chris, HW 10 and Team Evals due
• FINAL DD REVIEW DUE 5/2

4.2 Team Information

Ryan Stewart | ryan.j.stewart@colorado.edu | Aerospace Engineering
Howie Ritter | howard.ritter@colorado.edu | Mechanical Engineering
Joel Marquez | joel.marquez@colorado.edu | Computer Science
Luz Ibarra Perez | luib0557@colorado.edu | Astrophysics
Marisa Exnicious | marisa.exnicious@colorado.edu | Aerospace Engineering
Luke Beasley | luke.beasley-1@colorado.edu | Aerospace Engineering

5.0 Budget and Weight

The budget for Team Nacho Libre will be managed by Marisa Exnicious and Luz Ibarra. All receipts will be logged and meticulously organized so that Team Nacho Libre does not go over budget.

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<tr>
<th>Material</th>
<th>Quantity</th>
<th>Source</th>
<th>Weight</th>
<th>Cost</th>
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Team Nacho Libre
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*Team Nacho Libre*
6.0 Test Plan and Results

Prior to launch, Team Nacho Libre plans to conduct a minimum of 10 tests in order to be fully certain that Project S.C.I.E.N.C.E. is fully operational. To date, no tests have been completed but dates have been set within the schedule for when the tests need to be completed by.

**Drop Test**: For the drop test, Project S.C.I.E.N.C.E. will be dropped from the bridge outside of the DLC while at its full launch weight to simulate a hard landing. The team will ensure that the landing area is clear of any people or animals that could be hurt by the falling balloonsat. The box will be studied for any defects including breaks in the structure and movement of masses within the box. Repairs and revisions will be made as necessary.

**Whip Test**: The whip test will involve a team member holding Project S.C.I.E.N.C.E. from the end of a string while swinging it in circular patterns at a high velocity. This will simulate the back and forth whipping of the box during the first few seconds of takeoff and after burst. To ensure the safety of the team, the whip test will be performed in the wide open area of the business field while the rest of the team who is not swinging the box will stand far enough away that if the box were to come undone from the string, it will not have the chance of hitting anyone. The team will also make sure no one else gets closer than them during the test. The box will then be studied and altered if necessary.

**Stair Test**: To perform the stair test, Team Nacho Libre will place Project S.C.I.E.N.C.E. at the top of an empty flight of stairs, and the box will be kicked down at full weight by a team member. The team will make sure the bottom of the stairs is clear and no one attempts to walk up the stairs while the test is being done. This kind of event will likely occur during a hard landing after burst, and the box will be repaired and redesigned to better survive such an occurrence, if necessary.

**Data Testing**: Each Arduino will be tested separately to make sure that each is collecting and recording data properly. On the ground, the sensors will be operated in normal conditions, and a team member will scan the SD card to see if any data is actually recorded.

**Temperature Test**: The temperature test will involve placing the BalloonSAT into a cooler filled with dry ice for approximately 3 hours. The dry ice will simulate the very cold temperatures of the upper atmosphere, which can dip down to -50°C. This test will involve all of the equipment Team Nacho Libre will be operating at altitude, so it can be made certain that all parts will operate at these extreme temperatures.

**Mechanism Soft Test**: The mechanism soft test will simply involve testing the door opening mechanism on the ground in normal conditions. This will give Team Nacho Libre a starting point with the design so it can possibly be redesigned to be better or more efficient. The box will not be tampered with and only the mechanism will be tested by itself.

**Mechanism Hard Test**: The hard test will be similar to the soft test, but the mechanism will be tested in simulated flight conditions. This will bring together the whip, drop, and stair test, but with the mechanism integrated into the box. The drop test will make sure that none of the parts come free from the track, and the stair test will do the same. During the hard whip test, the mechanism will be told to open during the rapid spinning of the box. This will be done to make sure that the box can deploy no matter what situation it is in and can retrieve data.

**Camera Test**: Before launch, the camera will be tested to make sure that it is constantly taking pictures at 15 second intervals. This will also be tested during the temperature test to make sure that the camera will work during the coldest parts of the flight.
**Altitude/Software Test:** The altitude/software test will involve the team taking Project S.C.I.E.N.C.E. up the Flagstaff Trailhead to make sure that the box will deploy at altitude. To do this, the Software team will implement dummy code that will have the box open at the pressures at the top of the trail, as opposed to those seen in the upper atmosphere. This test will make sure that the code is responding correctly and that the Arduino is commanding the servo to open the doors at the correct altitudes.

**Mission Simulation Test:** This test will be conducted in tandem with the Altitude/Software test. After the team recovers and analyzes data from the A/S test, a second pass will be made up the Flagstaff Trailhead, but everything will be integrated into the box, including petri dishes, heater, and camera. The box will be held outside of the team vehicle to allow for contact with the moving air and possible microbes. The doors, assuming they pass the Altitude/Software test, will open and collect these microorganisms during the simulated flight. Afterwards, the data from both Arduinos will be collected and checked for accuracy. The petri dishes will undergo a short period of culturing to see if anything about the capturing mechanism needs to be changed.

### 6.1 Safety

Team Nacho Libre is determined to design, build, and launch Project S.C.I.E.N.C.E. without any injuries to any team members or passerby. To accomplish this, safety goggles will be used whenever any machining or soldering is done to avoid any possible eye injuries. All of the subsystem tests will be conducted in an organized, pre-planned, and efficient manner, so as to avoid any possible injuries among the team. All of the tests will be performed by a group of two or more to make sure that any injuries that do occur can be taken care of swiftly and professionally. Team members will seek training for any job or build that requires special skills or tools that are normally unavailable. Team Nacho Libre will make sure test sites are clear of passerby before proceeding with the intended test, and afterwards, all traces of testing will be cleared and disposed of as necessary. The whip test and the mechanical hard test will be performed in areas where there are no windows nearby. The petri dishes will be disposed of safely and ethically through the team’s biology contact, Dr. Paul Carini. All tools will be used properly and respectfully and all exacto blades will be stored safely when they are not in use. All University of Colorado Boulder policies will be studied and respected during testing, and no private property will be encroached upon during any of the tests.

### 7.0 Expected Results

Team Nacho Libre expects to observe temperature outside of the BalloonSat will decrease as the balloon rises due to the diminishing of Earth’s atmosphere and the increased distance from Earth, a geothermal heat source (Figure 4). The internal temperature sensor is expected to experience some of the variation of the outside temperature sensor for the same reasons, but the fluctuation in temperature should be much less dramatic due to the insulation of the structure. The slight upward trend seen in the

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Figure 4
The graph is due to the box passing through the ozone, where the atmospheric temperature tends to heat up due to radiation.

The expected data from the accelerometer (Figure 5) should be positive in the z-direction during the ascent and then negative during descent. The data will reflect positive and negative values in the x-direction throughout the flight as the unit is expected to chaotically spin for the duration.

The air pressure (Figure 6) is expected to reduce with altitude as well. This can be attributed to the fact that there will be less atmosphere above the sensor, and therefore less air pressing down on the BalloonSat.

Team Nacho Libre expects that humidity (Figure 7, following page) will also decrease as altitude increases, similar to air pressure and temperature. This can be substantiated by the fact that temperature decreases as altitude increases, and colder air retains less moisture. Team Nacho Libre has tested the given sensors in the Arduino workshops and will continue to test all of our sensors in known conditions to ensure accuracy and functionality. These sensors will store their data on SD cards, ultimately to be retrieved after flight. This data will be retrieved also during the test phases to ensure that it is accurately and efficiently recorded and transferred.

Team Nacho Libre expects to find that as altitude and UV radiation increases, the number of colonies of microbes collected will decrease along with the variety of different types of microbes (Figure 8, following page). This makes sense because only the hardier microbes will sustain as the environment becomes harsher. The procedures of data collection for the microbial aspect of the project will include exposing a sterile petri dish to air at the desired altitude and then culturing these collected samples to grow the present microbes. These cultured samples will be analyzed and compared to assess the hypothesis’ validity. For Project S.C.I.E.N.C.E, Team Nacho Libre has begun to test the microbe collection and culturing processes by culturing an initial petri dish with a breath sample from one of the team members. To continue this process, Team Nacho Libre is consulting with Dr. Paul Carini to refine these practices and ensure that the microbial samples do not become contaminated and the mission’s results are accurate.
Comparatively, Team Nacho Libre’s expected data is accurate with respect to other test studies that have been done. The following graphs show actual data from previous scientific studies that appear to bolster the team’s various hypotheses about their data. In accordance with the above figures, the temperature, pressure and humidity tend to drop with respect to increased altitude, while UV radiation tends to increase. See Figure 9 for temperature data, Figure 10 for pressure data, Figure 11 for humidity data, and Figure 12 for UV intensity data. Acceleration data will be very specific for this mission and therefore cannot be compared accurately to other sources.

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6 https://www.classzone.com/books/earth_science/terc/content/investigations/es1702/es1702page05.cfm
7 https://gregklein.wordpress.com/2011/01/19/bmp085-pressure-sensor-at-high-altitude/
8 http://www.societyofrobots.com/space_balloon_humidity_test.shtml
9 http://ep.faculty.brynathyn.edu/ES110/winter11/space/uv.html
Figure 11

Figure 12