Colorado Space Grant Consortium

**Gateway to Space**
**Fall 2014**
**Design Document**

Project Invictus

Team Orion

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Dec 15, 2014
Revision D
Revision Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B</td>
<td>Conceptual and Preliminary Design Review</td>
<td>10/14/2014</td>
</tr>
<tr>
<td>D</td>
<td>Analysis and Final Report</td>
<td>12/15/2014</td>
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1.0 Mission Overview

1.1 - Mission Statement:
The mission of Team Orion is to expose bacteria to a near space environment in order to determine if they can survive the extreme conditions with the hope of discovering a bacteria that could be useful on a human mission to an extraterrestrial body. In addition, Team Orion will also attempt to determine which conditions of the flight had an effect on the bacteria while adhering to the mission requirements set by the Gateway to Space class.

1.2 - Purpose:
During preliminary research for project ideas, the team came across an article about a small organism living in space on the International Space Station called a Tardigrade or Water Bear (Bordenstein, n.d.). The interesting thing about finding the Tardigrades in space was that no one had put them there. They had managed to get hundreds of miles above the earth onto the ISS all on their own. The main theory is that when the ISS was first launched 16 years ago the organisms had latched on and rode up from earth. This means they have been there for a significant amount of time surviving on the outside of the ISS in space (Fathima, 2014). After doing further research on the topic of bacteria in space the team found out that astronauts on the ISS conducted a 553-day experiment in which they exposed bacteria to the vacuum of space. Though some bacteria died some of it survived all 533 days and is now being studied for future space projects. Team Orion’s mission procedure will differ from NASA’s but they will both test the survivability of bacteria above Earth’s surface.

Over the last few decades, NASA has been looking at bacteria to use in space to help with detection or removal of harmful chemicals or other bacteria that are harmful to humans (Marconi, 2005). Some research has been done on earth for possible uses for bacteria in an extended human space mission and with so many known species on earth there are some bacteria that will be extremely helpful to humans during these trips. Based off these preliminary findings, it is predicted that bacteria will play a large role in a manned mission to Mars because they require very little resources to cultivate, reproduce rapidly, are easy to maintain, and are very resilient to extreme conditions (Dillow, 2010). However, more research needs to be done first and that is where Team Orion wants to help.

1.3 - What is Expected to be Discovered:
Bacteria are divided into two main categories which are Gram-positive and Gram-negative. The difference lies in the outer structure, Gram-positive bacteria have a thick cell wall with more peptidoglycan while Gram-negative have only a thin membrane for an outer layer and very little peptidoglycan which is shown in the graphic below.
To determine which type of Gram a bacteria is biologist use a stain to color the cell violet. When a second stain is introduced Gram-negative bacteria turn red or pink while the Gram-positive bacteria stay violet. The majority of bacteria fall into the Gram-positive and Gram-negative categories but there are a few exceptions. Since the method of identification does not work for every type of cell not every strain of bacteria can be classified as a Gram-positive or a Gram negative cell. Some examples of this are acid-fast bacteria or Gram-variable bacteria (Diffen, n.d.)

Gram-positive and Gram-negative bacteria both play very different roles in everyday life on earth. It is estimated that 90-95% of Gram-negative bacteria are pathogenic which means they tend to be harmful to humans and develop resistance to antibiotics quickly. These traits are not ideal for humans currently but if manipulated correctly have the potential to be very helpful. Gram-positive bacteria tend to be non-pathogenic and have a much wider variety of uses for humans. Many Gram-positive cells secrete large amounts of enzymes and can be used to make many different things including antibiotics, biofuels, gunpowder, and TNT. (Diffen, n.d.)

Team Orion decided that testing this trait in bacteria would help provide the most useful information for future research. For example, if it is found that the Gram-negative bacteria cannot survive the harsh conditions because of their thin outer wall then it is possible to eliminate other Gram-negative bacteria from future tests making the tests more efficient. On the BalloonSat, Team Orion plans to send up and test Bacillus Subtilis (B. subtilis) which is Gram-positive and Escherichia coli (E. coli) which is Gram-negative. Both bacteria are harmless to humans (the E. coli is a laboratory strain that has been modified to be safe for testing purposes) and are considered the Gram-positive/negative versions of each other (Koeng Biotech, n.d.). Since the bacteria are very similar in other aspects such as their genes the survival rate of the two will most likely depend on if they are Gram-positive or Gram-negative.

During the flight, radiation, temperature, and pressure will all be monitored to determine which variable had an effect on each type of bacteria. Due to the limitations of a BalloonSat the test bacteria will have one or more variables affecting them at a time but its possible to piece together this data to find which variable most likely had the biggest effect. In the unlikely event that all bacteria sent up on the BalloonSat dies while the control bacteria on the ground survives Team Orion would unfortunately be unable to
pinpoint the exact variable that caused the 100% death rate from the flight data alone. However, it would be very easy to do a few ground tests on the control bacteria left such as exposing them to extremely low temperatures and seeing the results, this would either pinpoint the cause of death or eliminate that variable for the cause of death. In addition to the two types of bacteria Tardigrades will also be sent up on the flight as another control for the experiment. If the Tardigrades do not survive the flight then other factors not from the flight may have caused the Tardigrades and the bacteria to die. This assumption can be made since it is known that if Tardigrades can survive the more brutal environment of the surface of the ISS for many years then they will be able to survive the short flight to 30km and any condition they are exposed to. The main control set of bacteria and Tardigrades will remain on the ground in the lab during the flight to compare with the flight bacteria. With these controls and multiple sets of bacteria flying, Team Orion hopes to not only determine which bacteria can survive the best in a near space environment but also what factors, if any, cause the bacteria to die.

2.0 Requirements Flow Down

This section details the requirements for completing Project Invictus. Some of the considerations are general and apply to any project involving sending a payload to near space, whereas other considerations, mainly requirement 1 and its subrequirements, are specific to Project Invictus. Requirement 0 is very straightforward and will be completed by Professor Koehler, whereas requirements 2 and 3 are Team Orion’s responsibilities.

<table>
<thead>
<tr>
<th>Level 0 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 Project Invictus shall fly on a lighter than air weather type balloon along with other satellites.</td>
</tr>
<tr>
<td>1 Project Invictus shall expose gram positive and negative bacteria as well as Tardigrades, a microorganism, to a variety of near space conditions.</td>
</tr>
<tr>
<td>2 Project Invictus shall measure the near space conditions and record the resulting data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 1 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement 0: Project Invictus shall fly to 30 km.</td>
</tr>
<tr>
<td>Requirement 1: Project Invictus shall expose Gram-positive and negative bacteria as well as Tardigrades, a microorganism to a variety of near space conditions.</td>
</tr>
<tr>
<td>1.0 Project Invictus shall carry three species, Bacillus subtilis,</td>
</tr>
</tbody>
</table>
Project Invictus

<table>
<thead>
<tr>
<th>Requirement 2: Project Invictus shall measure the aforementioned near space conditions and record the resulting data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>2.1</td>
</tr>
<tr>
<td>2.2</td>
</tr>
<tr>
<td>2.3</td>
</tr>
<tr>
<td>2.4</td>
</tr>
</tbody>
</table>

3.0 Design

3.1 - Design Plan Overview:
Team Orion will be sending an 18.5cm x 17.5cm x 17.5 cm (+/- 0.1 cm), exterior dimensions, cube satellite to the upper atmosphere. The satellite will have various scientific sensors to determine the conditions, such as temperature, humidity, and pressure throughout the flight. Team Orion will also have experimental testing on radiation exposure and the effects on three types of bacteria. The plan is to launch via a helium balloon with the satellite connected by a flight string. Team Orion does not only plan to launch but also plans to recover the satellite in order to collect data to verify the experiments.
3.2 - Structural Design:

The structure of Team Orion’s BalloonSat will be made up of foam core. Three half sheets of foam core have been supplied by the Colorado Space Grant Consortium. The foam core will be built into an 18.5cm x 17.5cm x 17.5cm box, and the instruments and sensors will be placed inside. Interior design will be as follows: the batteries will be lined up along the interior wall, the heater block system will be placed by the batteries, Arduino 1 and Arduino 2 (and corresponding sensors) will be on opposite sides of the interior, and the camera is placed next to the batteries and aligned with the camera slot. As shown in the drawing below there is a compartment within the box that will expose conditions outside of the box for two sets of petri dishes. This compartment is insulated from the rest of the box and has holes to allow air flow from outside the box into the compartment. On the outside of the foam core box, there will be a United States of America flag sticker as well as contact information for the team and the Colorado Space Grant Consortium.

![Diagram of BalloonSat structure]
3.3 - Scientific Instruments/Experimental Design:

The payload will consist of multiple sensors and instruments to collect scientific data of the flight conditions such as the surrounding temperature, humidity, pressure. Project Invictus will consist of living bacteria and the effects on these bacteria at high radiation exposure, found in near space environments. Two strands of bacteria and one microorganism have been chosen for the mission, and they are, *Escherichia coli* (E. coli), *Bacillus Subtilis* (B. subtilis), and Tardigrades.

- Accelerometer – From launch until landing, Team Orion is using an accelerometer to measure the G forces exerted on the BalloonSat. The accelerometer is connected to Arduino #1, in an analog pin, data will be collected through this code and stored on the SD card. The accelerometer for Team Orion was supplied by the COSGC.

- Humidity Sensor – As the altitude increases, the humidity is expected to decrease and Team Orion is going to measure the different humidity by using a humidity sensor. This sensor is in an analog pin on Arduino #1, data will be collected through this code and stored on SD card. The humidity Sensor was granted to Team Orion by the COSGC.

- Pressure Sensor– Atmospheric pressure will decrease to 0.2 psi as Orion’s satellite approaches near space, so accordingly a pressure sensor will be connected to an analog pin on Arduino #1 and the data will be transferred to the corresponding SD Card for data collection. The pressure sensor was also supplied to Orion’s satellite by the COSGC.

- Temperature Sensors – Temperature will be varying throughout the flight, so Team Orion has brought three temperature sensors for Project Invictus. One sensor will measure the internal temperature, one will measure the temperature inside the compartment simulating the outside environment and the last will be
measuring the external temperature. The internal temperature sensor will be connected to an analog pin on Arduino #1 and the other two will be connected to analog pins on Arduino #2. The temperature sensors have been provided to Team Orion’s BalloonSat via the COSGC

- **Geiger Counter**—As altitude increases, radiation exposure will rise to 700 counts/minute. The Geiger counter has a 30% accuracy of a known Geiger counter on the CU Boulder campus. The Geiger counter will detect this radiation the Satellite, and specifically the bacteria are exposed to. The Geiger counter will be connected via an analog pin to the Arduino #2 and the corresponding SD Card to transfer and store data. The team found and ordered the Geiger counter from Sparkfun.com.

- **Biological Specimen**
  - E.Coli – The E. Coli will be supplied from the MCDB Department at CU Boulder via Professor Joel Kralj
  - B. subtilis – The B. subtilis will be supplied from caroline.com
  - Tardigrades – The Tardigrades will be supplied from caroline.com

- **Petri Dishes and Nutrient Agar** – Professor Joel Kralj has been a great resource and is going to help Team Orion supply the 6cm petri dishes as well as the nutrient agar to place in the bottom of the dishes, where the bacteria will reside.

- **Sustainability of Bacteria** – Professor Kralj has offered to instruct the team how to culture and sustain bacteria. All lab work will be done by team members only, and will take place and be stored in Professor Kralj’s Lab located on East Campus of CU Boulder. Team Orion will culture the bacteria 12 hours before launch on November 15th, which will give each bacteria 3-4 more weeks of sustainable, independent life. It is essential to culture the specimen so contiguous to flight in order to most efficiently analyze the results. The closer the culturing of the flight specimen to the actual flight time the more divergent results in colony count. Testing has been conducted to ensure the effectiveness of this procedure and it was determined that culture of all specimen can be completed in under a half an hour. This allows for plenty of time for any unexpected failures and decreases the time risk for this particular procedure.
3.4 - Command and Data Handling Design:

Team Orion will be using two Arduino Unos along with two compatible SD shields with memory cards to retrieve data from the mission. All six analog pins will be used for computing data from Arduino#1, and three analog pins will be used for computing data on Arduino #2. A camera and memory card setup will be flown for the collecting and storage of visual data throughout the flight. The COSGC provided both of the Arduinos, corresponding SD shields, camera, and memory cards. Certain members of Team Orion have written code for each arduino and corresponding sensors so data collection is possible through specific code when the satellite is retrieved.

3.5 - Power Supply:

Project Invictus will consist of multiple sub power systems that will power the scientific instruments, the thermal system, and the command and data handling. The main power source will be five Duracell Procell 9 Volt batteries and one 3.6V Lithium Ion battery to power the camera. Team Orion received a supply of these 9V batteries, as well as the lithium ion battery, from the COSGC to power the BalloonSat. The power subsystems provide power to different systems in the BalloonSat. There is concern that as the temperature drops to -20\degree C, the 9V batteries are no longer in operating range.

Breakdown:
- 2 x 9V Battery – Arduinos (one 9V for each Arduino)
- 3 x 9V Battery – Heater Block
- 1 x 3.6V Lithium Ion Battery – Camera

3.6 - Thermal Design:

Interior temperature will be kept warm by heater block, which the team put together, and received via the COSGC. The heater system is connected to 3 9V batteries for the power source. The job of this heater system for the mission is to keep the interior temperature of the satellite above -10\degree C, for the entirety of the flight.

3.7 - Imaging Systems Design:

For the duration of the flight, a camera will be on board the payload to take pictures for visual results from launch to landing. The camera will be connected to a memory card so the pictures taken can be collected as visual data. This is crucial in order
to have visual evidence of the near space conditions. The lens will have to be exposed to the outside environment to collect the visual data. The camera on board is a Canon PowerShot A3400 IS Digital camera. It has the capabilities of 16 Mega Pixels. The COSGC has provided Team Orion with both the camera and the memory card.

3.8 - Interfacing Systems Design (Functional Block Diagram):

The Functional Block Diagram, showing how all the subsystems function as a whole. The subsystems are the Thermal system, Imaging system, environmental system, and the experimental system. Each system has a power source, 9 Volt batteries or a Lithium Ion Battery. The Imaging system consists of the camera, memory card, and Lithium Ion Battery, all provided by the Gateway to Space class. The Thermal System consists of three 9V batteries, a switch, LED light, and heater block, which also were provide by the Gateway to Space class. The environmental system involves the accelerometer, humidity sensor, interior and exterior temperature sensors, pressure sensor, a switch, an LED light, an Arduino Uno and corresponding SD Shield/Card, which were provided via the Gateway to Space class as well. The Experimental system is directly related with Project Invictus. The hardware involved consists of a Geiger counter, another Arduino Uno with corresponding SD Shield/Card, a switch, an LED light, and a third temperature sensor. Team Orion decided to not fly a compass, in order to open up analog space on the Arduino Uno for environmental data, and also added a temperature sensor to the Arduino Uno for experimental data.
3.9 Concepts of Operations Design

The CONOPS diagram shows the flight plan from preflight to postflight. Twelve hours prior to launch, the B. Subtilus and E.Coli will be cultured in petri dishes, and Tardigrades will also be put into petri dishes. Then all biological test subjects will be stored for launch in a refrigerator, in order to minimize growth before flight. Five minutes before launch, the biological test subjects will be placed and sealed into the BalloonSat. Once the bacteria and Tardigrades are sealed in the box, the top panel will be sealed up with aluminum tape, and all switches will be flipped to “on” positions. After the switches are turned on, the sensors will begin to collect environmental and experimental data during ascent, burst, and descent. Once the BalloonSat lands, Team Orion will retrieve the box and turn all switches to “off” positions, as well as transfer the bacteria and Tardigrades to Professor Krajl’s lab for incubation and data analysis. Also all SD and memory cards will be connected to computers for data analysis. Once all data is collected, memory cards will be cleared and the BalloonSat will be prepared for another flight.
3.10 Parts List

<table>
<thead>
<tr>
<th>Part</th>
<th>Part Number</th>
<th>Source</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geiger counter</td>
<td>SEN-11345</td>
<td>SparkFun Electronics</td>
<td>$149.99</td>
</tr>
<tr>
<td>Chamber Temp Sensor</td>
<td>SEN-10988</td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
<tr>
<td>Interior/Exterior</td>
<td>SEN-10988</td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
<tr>
<td>Temperature Sensors</td>
<td>COM-11028</td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>TBPDA50015PGUCV</td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
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<td>Humidity Sensor</td>
<td>SEN-095969</td>
<td>COSGC</td>
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</tr>
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<td>Arduino Uno (#1 and #2)</td>
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<td>COSGC</td>
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<td>SD Shields</td>
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<tr>
<td>Camera</td>
<td></td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
<tr>
<td>SD Card</td>
<td></td>
<td>COSGC</td>
<td>$0.00</td>
</tr>
<tr>
<td>Heater Block</td>
<td></td>
<td>COSGC</td>
<td>$0.00</td>
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<tr>
<td>Bacillus subtilis</td>
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<td>Flinn Scientific</td>
<td>$32.30</td>
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<tr>
<td>Tardigrades</td>
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<td>Carolina.com</td>
<td>$38.37</td>
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<tr>
<td>Escherichia coli</td>
<td></td>
<td>MCDB Dept. CU Boulder</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

4.0 Management

4.1 - Introduction:

Adam Owens is Invictus Project Manager for Team Orion and is responsible for overseeing the development of the mission throughout the semester. He ensures that the team meets all deadlines and requirements given by Chris Koehler. Team meetings will be held periodically to ensure that each team member is following them. Project Invictus is made up of seven team member responsibilities: Structure, Biology, Power, Sensing, Software, Testing and Data. Each member of Team Orion is extensively responsible for one system of Project Invictus and also has an overlapping assistant role under each system lead.
4.2 - Organization Chart:

![Organization Chart Image]

4.3 - Team Role Description:

Jae Kim is Structure Lead and is responsible for designing and building the underlying structure that will house all of the biological subjects and other hardware. Jason Ryan is Biology Lead and is responsible for creating the ideal conditions for the bacteria and Tardigrades in order to give Team Orion useable results. Abdiel Agramonte Moreno is Power/Thermal Lead and is responsible for ensuring the BalloonSat has a sufficient power and temperature to operate throughout the mission. He will also still be in control of the finances for Team Orion. Nick Gentz is Sensing Lead and is responsible for ensuring each sensor included in the BalloonSat gives
expected data for the entirety of the mission. Tyler Voiles is Software Lead and is responsible for coding the Arduinos to perform as desired throughout the mission. Randy Molinar is Testing Lead and is responsible for engineering tests to ensure that every component of the BalloonSat will operate as intended during the mission without failure. Jason Cheskis is Data Lead and will is responsible for the collection of data from the BalloonSat.

4.4 - Schedule:
The following schedule will be followed explicitly and will only be altered with approval by the Team Leader. Team meetings will be held every Monday evening in the ITLL study rooms with additional meetings as necessary.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>9/22/2014</td>
<td>Proposals Due</td>
</tr>
<tr>
<td>9/23/2014</td>
<td>Arduino – Part II (In-Class)</td>
</tr>
<tr>
<td>9/25/2014</td>
<td>Arduino Part III/IV (In-Class)</td>
</tr>
<tr>
<td>9/26/2014</td>
<td>Authority to Proceed (ATP) &amp; Team Meeting</td>
</tr>
<tr>
<td>9/29/2014</td>
<td>Order Hardware</td>
</tr>
<tr>
<td>10/02/2014</td>
<td>Meet Assistant Biology Professor Joel</td>
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<tr>
<td>10/06/2014</td>
<td>Team Meeting (Begin DD Rev A/B &amp; PDR)</td>
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<tr>
<td>10/08/2014</td>
<td>Design Complete</td>
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<tr>
<td>10/09/2014</td>
<td>Meeting With Joel (Practice Culturing E-Coli)</td>
</tr>
<tr>
<td>10/10/2014</td>
<td>Meeting with Joel (E-Coli Practice Results)</td>
</tr>
<tr>
<td>10/13/2014</td>
<td>Team Meeting (Practice PDR presentation)</td>
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<tr>
<td>10/14/2014</td>
<td>Preliminary Design Review (PDR) &amp; DD Rev A/B Due</td>
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<td>10/14/2014</td>
<td>Acquire All Hardware</td>
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<tr>
<td>10/15/2014</td>
<td>Begin Prototype Build</td>
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<tr>
<td>10/18/2014</td>
<td>Arduino Geiger Counter Coding</td>
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<td>10/20/2014</td>
<td>Team Meeting (Progress Update)</td>
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<tr>
<td>10/20/2014</td>
<td>Petri Dish Stress Testing</td>
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<tr>
<td>10/21/2014</td>
<td>Order Bacillus Subtilis and Tardigrades</td>
</tr>
<tr>
<td>10/21/2014</td>
<td>Sensor Calibration/Testing</td>
</tr>
<tr>
<td>10/23/2014</td>
<td>Acquire Bacillus Subtilis and Tardigrades and Culture with Joel</td>
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<tr>
<td>10/24/2014</td>
<td>Prototyping Design Complete</td>
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<tr>
<td>10/27/2014</td>
<td>Team Meeting (Progress Update)</td>
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<tr>
<td>10/27/2014</td>
<td>Testing (Whip Test, Drop Test and Stair Test)</td>
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<td>10/28/2014</td>
<td>Testing (Vacuum Test and Cooler Test)</td>
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<tr>
<td>10/30/2014</td>
<td>In-Class Team Time</td>
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<td>10/31/2014</td>
<td>Testing Final Design Complete</td>
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<tr>
<td>11/03/2014</td>
<td>Team Meeting (Progress Update)</td>
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<td>11/04/2014</td>
<td>In-Class Mission Simulation Test</td>
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<td>11/05/2014</td>
<td>Team Meeting (Discuss Launch Readiness)</td>
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<tr>
<td>10/10/2014</td>
<td>Practice LRR Presentation</td>
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5.0 Budgets

5.1 - Financial/Weight Inventory:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Supplier Information</th>
<th>Cost Including S&amp;H</th>
<th>Mass (g)</th>
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<tbody>
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<td>SparkFun.com</td>
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<td>Tardigrades</td>
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<td>9v Batteries</td>
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<td>Item</td>
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<tr>
<td>3.6V Battery (Camera)</td>
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<td>Provided by Biology Department</td>
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<td>E.coli</td>
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<tr>
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<td>Provided by Gateway to Space Class</td>
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We began project Invictus with a projected final weight of 994 grams based off of our projected design and weight information we had for individual components. However, after much configuration to the satellite we ended up with a final weight of 1105 grams. The difference in projected and final weight occurred to certain miscalculations of weight of components, added weight from hot glue and tape, and a few last minute fixes. A far as our budget, we began with a projected amount of $219.97 and ended with an additional team budget of $161.00. Our projected team budget was primarily utilized on the Geiger counter and various bacteria we used in our mission. Since those main expenses used up most of our team budget, we had to divide up any extra expenses amongst the team members.

5.2 - Company information:

- SparkFun Electronics- SparkFun is an online retail store that sells the bits and pieces to make your electronics projects possible. www.sparkfun.com
  Phone Number: 303-284-0979
  Address:
  6333 Dry Creek Parkway
  Niwot, CO 80503

- Flinn Scientific- Carolina Biological offers science supplies and materials for use in the science classroom.
6.0 Test Plan and Results

6.1 - Whip Test:

This test will put the BalloonSat through similar conditions it will face in flight. This test specifically will test the payload to the G forces it will face in near space. There will be weight contained in the structure during the whip test to simulate the mass of the payload. The test will be done by tying the payload to the end of a string and having a team member spin it above their head in order to simulate the G forces the BalloonSat will experience during flight. The whip test is required to make sure the BalloonSat will stay intact during the flight. Safety cautions include keeping the test area clear and setting a test location that is appropriate and clear of windows.

6.2 - Drop Test:

The drop test is done to make sure the BalloonSat can survive a single large impact to replicate a similar landing scenario. The BalloonSat will be dropped from a one story platform onto a hard surface to see if it can survive the impact. The structure must be able to protect the payload, making this one of the most important tests. The drop test is crucial because a successful landing leads to data collection for the experiments of Project Invictus.

6.3 - Cooler Test:

Another factor to consider with the structure of the payload is the temperature it will experience in a near space environment. The payload has to be able to
withstand the extreme temperatures of the upper atmosphere it will be exposed to. To simulate these conditions the payload will be placed in a cooler with dry ice for about two and a half hours, which is roughly the total flight time. During this test, all hardware will be inside of the payload. The heater block will be directly tested because it is meant to keep the payload above -10 °C. This will ensure all of the hardware will also function correctly during these flight conditions.

6.4 - Arduino Uno Test:

The Arduinos are a crucial part of the mission so they need to be properly functioning for the flight. The Arduinos will be tested with each sensor individually and in conjunction with the other sensors. The Arduinos will be exposed to low temperatures during the cooler test, and low pressures during the vacuum test to ensure the Arduinos will survive.

6.5 - Sensor Tests:

Sensors that will be tested include the pressure sensor, temperature sensors, accelerometer, humidity sensor, and the Geiger counter. These sensors will be calibrated as well as tested to ensure accurate data collection during the flight.

6.5.1 - Pressure Sensor Test:

The pressure sensor will be calibrated by putting the sensor under a vacuum and zeroing out the pressure sensor output accordingly by adding a constant to the Arduino pressure sensor coding. The pressure sensor will then be exposed to normal outside pressure and its data will be compared to locally known pressure to ensure accuracy.

6.5.2 - Temperature Sensor Test:

The temperature sensors will be calibrated by performing a side by side calibration next to a trusted thermometer at different temperatures. The temperature sensors will then be tested by surrounding them with ice and making sure the output reads close to 0 degrees Celsius.

6.5.3 - Accelerometer Test:

The accelerometer will be calibrated by recording approximately 10 seconds of data with the accelerometer on each of its axes. The sensor can then be programmed to read one G when stationary on the surface.

6.5.4 - Humidity Sensor Test:

The humidity sensor will be calibrated by comparing the readings from the
humidity sensor to locally known atmospheric data and will be tested by exposing the sensor to different humidity settings such as low temperatures, a sealed container with desiccant, and above warm water (keeping safety in mind).

6.5.5 - Geiger Counter Test:

The Geiger counter will be calibrated by comparing the readings from the team Geiger counter to readings of a trusted Geiger counter from the Duane Physics Laboratory. The Geiger counter will be tested by placing a weak radioactive source such as Americium from a smoke detector, and looking for a feasible readout. The Geiger counter will also go through an additional round of durability testing, due to the unreliable reputation these Geiger counters have acquired throughout previous missions. The Geiger counter will be subjected to a vacuum and low temperature, by the following tests: the cooler test and the pressure test. These durability tests will be conducted with extreme care as to not destroy the Geiger counter.

6.6 - Camera Test:

The camera test will make sure that the camera takes pictures and saves them at the correct intervals during the flight. The picture shown below was taken with Team Orion’s Camera and shows that the camera is functioning properly.

6.7 - Stair Test:

The stair test is meant to simulate the landing and descent during the flight. The BalloonSat will be kicked down a large flight of stairs in order to simulate multiple collisions that may be present during the flight. The actual landing will most likely be less violent than the stair test, so if the BalloonSat survives, then the BalloonSat's structure will withstand the actual flight.

6.8 - Vacuum Test:

The vacuum test will be performed in order to ensure the box used to maintain surface pressure for the sets of petri dishes will maintain their structural integrity when exposed to a near vacuum. The aforementioned box will be sealed with a constant surface pressure and then be put into a bell vacuum chamber. If the box maintains surface pressure throughout the test with no structural failure, it shall be determined that the box will be strong enough to endure the actual flight to a near vacuum. If the box does fail and loses pressure during the test a stronger box will be necessary for the flight.
6.9 - Petri Dish Test:

Petri dishes identical to the dishes that will be used during flight will be incorporated in all of the other tests (ie. stair test, cooler test, drop test, whip test). This will ensure the dishes will not break or fracture at any time during flight. If the aforementioned petri dishes do indeed fracture or break during testing, Jae will design a mass efficient method to protect the petri dishes in high stress time intervals during flight. This method will be tested again using the each tested mentioned before to ensure the petri dishes remain intact regardless of any possible stress during flight. Sample culturing of E. coli and B. subtilis bacteria have been conducted with Team Orion’s biology contact, Joel, in his lab. The procedure shown in the left picture below is called serial dilution. Different concentrations of E. coli were cultured on 6 different petri dishes to determine an appropriate concentration of bacteria where individual colonies could be counted. The determined concentration was then used to test the culturing procedure on the B. subtilis bacteria. Results are then shown in the bottom right picture.

6.10 - Safety:

Safety is the number one priority when testing and building the BalloonSat. When working in workshops such as the ITLL team members will follow all rules and safety regulations. While testing the payload, there will be more than one team member present to make sure no bystanders get in harm's way and that the test is under control. This includes precautions such as handling dry ice with care and making sure the BalloonSat isn't dropped or kicked near anyone during testing. The whip test will be conducted in an area free of obstacles that could be damaged including but not limited to: windows, cars, and humans. Each team member also must know how to properly work with all of the equipment they need. If they do not have any experience with the equipment, they will need to take a workshop to learn how. Lastly, there will be no illegal activity at team meetings including but
not limited to use of drugs and alcohol, whether it is on campus or not. The E. coli is a modified laboratory strain that is safe for humans to work with with no protective gear, the B. subtilis is also safe for humans. Below is a letter from Prof. Joel Kralj concerning the safety of the bacteria.

Nov 13, 2014
To whom it may concern:

The cultures of E. coli and B. subtilis being used for this experiment are both classified as bio-safety level one, and pose no health hazard.

Please contact me if you have any questions or safety issues.

Prof. Joel Kralj
joel.kralj@colorado.edu

Results:

Whip Test: During the whip test the payload was not damaged at all. All mass simulators inside of the payload stayed intact and where they were from the beginning of the test. From this test it can be concluded that g force will not be an issue with this payload.
**Drop Test:** After this test the payload had slight damage to one of its corners. The corner was pushed in, but nothing on the inside was affected. Also one edge of the payload was beginning to break apart. In the next model of the payload the walls were cut closer to a 45 degree angle to secure it better. Also, more tape used on the edges to make a stronger bond.

**Stair Test:** This test showed faults in the lid of the payload. When this test was conducted the lid of the payload completely fell off, disposing all of its interior. The tape holding it had become weak. The edges that were starting to break in the drop test spread apart even more after this test. In the next model there was more insulation used on the lid to provide a tighter fit. There will also be more tape used along the edges of the lid as well as the other edges of the entire payload.
Cooler Test: This test will ensure all of the sensors will work in the extreme low temperatures of near space. During this test the BalloonSat was unable to maintain an adequate temperature on the interior and each of the sensors stopped functioning just under the two hour mark. To account for this loss of heat, insulation was added in conjunction to integrating a different heating system configuration where the resistors were pulled apart to create heat at different locations of the payload. The insulation will also allow the batteries to maintain a temperature that will allow them to function properly. The heaters are not designed to last longer than 90 minutes. The residual heat in the box keeps the interior box above -10 degrees Celsius for the duration of the flight.
Arduino Uno Test: The Arduinos have been tested with each sensor individually and with all of them together. The Arduinos are working as expected. They are properly collecting as well as analyzing the data. This ensures the functionality of the Arduino Unos as well as the sensors. Some of the readings for the sensors were inaccurate, but this was fixed with minor changes to the code.

![Cooler Test Geiger Counter Data (Abbreviated Test Run)](image)

Accelerometer Test: The accelerometer was placed on each of its axes individually and data was taken accordingly to show that when each axis is facing up/down there is approximately one G reading on the accelerometer.

![Accelerometer Test](image)

Camera Test: The camera has also been tested. The camera is properly set up and taking pictures every ten seconds. The camera is also saving the pictures to the SD card. Below is a picture of the camera box taken by the camera inside the BalloonSat.

![Camera Test Image](image)
Vacuum Test: During this test all pressure chambers were undamaged and able to maintain pressure. The Geiger counter properly functioned throughout the duration of the test. The temperature sensor showed there was a constant temperature. The pressure sensor data indicates the chamber was able to get within decimals of a vacuum.

Petri Dish Test: Each petri dish used in the aforementioned structural tests ended up with no structural damage. Additionally, with remaining dry ice from the cooler test, a Petri dish was placed in between two pieces of dry ice for 1 minute and dropped, as well as thrown down from 2.5 meters up with an initial velocity of approximately 16 m/s. After inspection, the dish revealed no signs of damage. Team Orion is confident that the petri dishes containing the most integral aspect of Project Invictus will maintain their structural integrity throughout the entirety of the flight.

7.0 Expected Results

Tardigrades have been proven to be resilient enough to survive in outer space; thus, it is expected that all of them will survive the experiment. However, it is not expected that all of the Gram-positive and Gram-negative bacteria will survive. Since the Gram-negative bacteria have significantly weaker cell walls than Gram-positive bacteria, it is thought that more Gram-negative bacteria will be killed than Gram-positive bacteria due to temperature, pressure, and radiation changes than the Gram-positive bacteria. Specifically, it is expected that the pressure changes will kill more than 75% of the Gram-negative colonies and around half of the Gram-positive colonies, while the temperature changes will kill around 60% of the Gram-negative colonies and 30% of the Gram-positive colonies. Additionally, Team Orion expects the differing radiation levels to affect the experimental groups equally, since whether or not a cell takes radiation damage has nothing to do with how thick its cell wall is. It is important to note that the differing radiation levels affect all of the experimental groups except for the control which will remain on the ground. Since Team Orion does not have a
way of selectively blocking radiation within the given weight requirements all trials onboard will be subject to the same amount of radiation. These expected results were derived from conversations with Team Orion’s Biology contact, Professor Joel Krajl.

Once the experiment is complete and the BalloonSat is recovered, the team can incubate the petri dishes and count the number of bacterial colonies that have formed in each of the petri dishes. Then, that number is divided by the average number of colonies produced by the control bacteria to create a percentage that indicates how well a particular petri dishes environment is suited to bacterial growth.
8.0 Launch and Recovery

Saturday November 15th, 2014 is the date at which the Team Orion BalloonSat will be launched. To minimize the risk of any preventable mistakes that may occur, Team Orion has created a detailed plan for launch day from start to finish.

**Launch Plan:**

- **At 4:30 am...**
  All team members will report to the parking lot adjacent to the ITLL with their respective hardware. Jason Ryan shall be responsible for the cooler containing the biological samples that were prepared the night before. Nick shall be responsible for hardware box containing tools that will be used to fix the satellite should there be any damaged caused to it for any reason. Jae shall be responsible for the aluminum tape that will be used to seal the satellite after the biological samples are added on-site. Adam shall be responsible for the satellite and its safety until launch. All team members are responsible for bringing phones for photographic documentation as well as communication.

- **At 4:45 am...**
  And no later than 4:45 am, Team Orion will begin driving to the launch site in Windsor approximately 49 miles away. Jason Ryan will drive Nick, Abdiel and Randy in his car while Jason Cheskis will drive Adam, Tyler and Jae in his car.

- **At 5:50 am...**
  Team Orion will arrive at the launch site and immediately perform a thorough inspection of the satellite to determine if it was damaged during transport. Adam and Nick will make repairs if necessary.

- **At 6:30 am...**
  Jason Ryan and Nick will transfer the biological samples from the cooler to the designated locations inside the satellite.

- **At 6:35 am...**
  Jason Cheskis and Tyler shall activate Arduinos 1 and 2 and acquire visual confirmation that all hardware including the Geiger Counter is functioning properly. Abdiel and Randy shall activate the heater and acquire confirmation that that the heater system is producing heat by touch. Abdiel and Jason Ryan shall activate the camera and acquire audible confirmation that the camera is taking pictures properly. Adam shall take multiple pictures of the satellite to document its pre-flight condition.
- **At 6:40 am...**
  
  Jae and Randy shall seal the satellite with the aluminum tape and install the satellite on the flight string with the flight tube and paper clip. At this point Adam will run through the checklist to ensure that everything has been completed and the satellite is ready for flight.

- **At 6:45 am...**
  
  Adam will report to Chris with a GO for launch.

- **At 6:50 am...**
  
  Adam will launch the Team Orion BalloonSat.

**Recovery Plan:**

As the biological payload is largely dependent on a quick and successful recovery, Jason Ryan will be responsible for the recovery of the BalloonSat. Directly after launch, the recovery team consisting of Jason Ryan, Adam, Nick and Abdiel will follow the satellite as closely as possible using the GPS unit attached to the balloon. As soon as the landing site is found Nick and Abdiel shall switch off Arduino 1 & 2 as well as the heating system. Adam and Abdiel shall take off the aluminum tape sealing the box. Then Jason shall carefully transfer all 4 sets of petri dishes from the box into the cooler for transport back to Joel Krajl’s lab where they will be incubated and analyzed in comparison to the control that remained in the lab for the duration of the flight. As for the flight data, Nick will be responsible for removing the micro SD cards from the Arduino’s and the SD card from the Camera and safely transporting them back to Boulder where they will be routinely uploaded to a computer. Adam will be responsible for getting the box safely back to campus where it will be imaged and repaired to flight ready conditions.

**Account of Launch And Recovery**

Launch took place on November 15th, 2014 at 6:50 AM and occurred as expected without any issues. Recovery was initiated very shortly after launch. After 4 hours of recovery, the BalloonSat had been recovered and taken back to Boulder for analysis of flight data and bacterial growth. Initially the payload at the landing site seemed relatively undamaged with only minor cosmetic scratches and dents on the exterior of the box. However, upon further inspection, it was discovered that the camera had become detached from the box wall, one solder joint was broken, one battery was disconnected, and the Geiger counter switch was off. As a result, it was found during data retrieval that Arduino #1 stopped recording data at T+60 minutes, Arduino #2 at T+83 minutes, the camera at T+93 minutes, and no Geiger counter data was recorded.
9.0 Results, Data Analysis, Failure Analysis, and Conclusions

After analysis of the sensor data from the BalloonSat flight, Arduino1 which controlled all of the required sensors (such as the accelerometer and pressure sensor) had lost power at around 60 minutes after launch. This happened because the connection between the battery and the switch was not soldered properly and disconnected. Arduino2, which controlled two temperature sensors and the Geiger counter, was found to have lost power at around 83 minutes in as a consequence of burst causing the battery to disconnect from the connector. Finally, the failure to check to see if the Geiger counter sensor was switched on (it has its own power switch that must be on at all times to take data) caused us to lose all radiation data for the flight. Nevertheless, the other sensors took good data for the duration of their operation. The trendlines of temperature (specifically the external temperature graph) show the progression of the satellite as it ascends through different layers of the atmosphere. At 31 minutes after launch, the balloon crosses into the stratosphere, in which the atmospheric temperature rises with altitude. Burst can be seen to occur around 82 minutes in, and Arduino2 briefly captures the temperature falling as the balloon starts to fall through the stratosphere. Additionally, the pressure sensor indicates that around 60 minutes in, the atmospheric pressure had already been reduced to 0.6 pounds per square inch, very close to what it would theoretically have read at the balloon’s peak.

Unfortunately, there was also an issue with the culturing of the bacteria that negatively impacted the experiment. It was found that none of the cultures of B. subtilis, including the control culture, yielded any growth. While it is hard to say what the definitive cause of this failure is, it is expected that an error came about when making the cultures the day before launch. However, the E. coli strain of bacteria yielded great results that are of experimental significance. First, it was found that the control culture of E. coli grew around 199 colonies over the duration of the flight, while the E. coli exposed only to high radiation had created 47 colonies, the lowest of any E. coli group on the flight. Since the high radiation-only group experienced the fewest stressors that could inhibit bacterial growth, it is thought that this culture is the result of human error in the culturing process. The culture exposed to low temperature and high radiation yielded 175 colonies, which means that those bacteria grew at a rate of 88% of the control. The next culture, which was exposed to high radiation and low pressure, yielded 115 colonies, which means that those bacteria grew at 58% of the rate of the control. And finally, the culture that was exposed to low temperature, high radiation, and low pressure yielded 57 colonies, which corresponds to a growth rate of 29%.
Team Orion’s goal was to discover if bacteria could survive near-space conditions, and if they could, to see whether or not having a cell wall would protect them further from the harsh environment. Even with the lack of data from the B. Subtilis cultures, Team Orion managed to make some valuable conclusions about the survivability of bacteria in space-like environments. The general trend of variable temperature being the most lenient environment, followed by variable pressure, and then by variable temperature and pressure, falls in line with the trend hypothesized. However, the magnitudes of these effects was in actuality less severe than predicted. It had been expected that temperature variations would reduce colonies by at least 60%, when in reality it reduces colonies by 12%. The same can be said of pressure variations, which reduces colonies by 42% when it was expected to reduce colonies by 75%. Additionally, this data supports the theory that pressure would have a larger effect on the growth of the bacteria than temperature would. Another important inference that can be made from the data is that the colony reducing effect of temperature and pressure together was greater than the individual colony reducing effects of temperature and pressure summed together. Lastly, the data shows that even bacteria with no cell walls, such as E. Coli, is capable of surviving in near-vacuum, frigid temperatures, and in zones of moderate radioactivity. E. Coli’s growth rate was severely impacted by these factors, but not enough to completely stop it from reproducing.
Best flight pictures:
Failure analysis
Geiger counter failure:

Immediately after recover when he bacteria was retrieved it was noted that the Geiger counter switch was in the off position and it was predicted that no Geiger counter data was recorded. This was later confirmed when no Geiger counter data was on the Arduino2 SD card. The reason for this failure was the Geiger counter switch had been in the off position. When the switch was turned on the Geiger recorded data to the SD just fine, the failure would repeat when the switch was turned off. After the flight turning the Geiger counter switch was turned on was added to the pre-flight checklist. The Geiger counter was also tested against a trusted Geiger counter and a radiation source since no preflight calibration was performed.

Geiger Counter Calibration:

To calibrate the Geiger counter, it was decided that comparing it to the readings of an industrial Geiger counter, near and away from a radioactive source, would be the best method. The industrial counter that Team Orion used through this process belongs to the Duane Physics Laboratory, at CU. The radiation source used in the calibration was Thorium-232. Readings from Team Orion’s Geiger counter showed 23.14 CPM while away from a radioactive source and 632.86 CPM while close to the Thorium. The lab’s Geiger counter showed 75 CPM away from radioactive sources and 2200 CPM near the Thorium. Dividing the ambient CPM’s of each counter and dividing the CPM near Thorium of each counter both yield the same number, .3. This means that Team Orion’s Geiger counter detects .3 times the number of counts that the lab’s counter detects. This ratio can easily be used to figure out how many counts the lab’s counter would have gotten had it been exposed to the same conditions as Team Orion’s counter.

Error Status: Fixed
**Arduino1 failure:**
Immediately after recovery it was noted that a battery wire connection had been broken during the flight. After the SD card in Arduino1 was analyzed it appeared that the wire had broken after 60 minutes into flight and Arduino1 had lost power and stopped recording data. The connection came loose and broke because of a faulty soldering connection and the weak wire that is used in the power supply cord. Once the wires were reconnected the Arduino recorded data just fine. When the wires were pulled apart Arduino1 lost power thus repeating the failure. In order to fix the broken wire the connection was re-soldered and hot glue was added around the connection to increase the strength. This connection was tested by pulling on the connection to make sure the wires stayed secured. **Error Status: Fixed**

**Arduino2 failure:**
Immediately after recovery it was noted the battery to Arduino2 had become disconnected. When the data was retrieved from the SD card it appeared that the battery had become disconnected about 83 minutes into flight. When they battery was reconnected Arduino2 recorded data and when the battery was disconnected Arduino2 shut down, thus repeating the failure. Along with the main data file on the SD card there were several other smaller data logs of unusable data that suggested the battery connector would touch the battery terminal periodically on the way down further confirming that this was the only failure. In order to fix this failure the connection was tightened with pliers and re-secured. To test the strength of the fixed connection the battery was pulled on and took two hands and a reasonable amount of force to remove the battery from the connector. **Error Status: Fixed**

**B. subtilis failure**
After the period of incubation when counting the colonies it was noted that most of the B. subtilis petri dishes had 0 colonies, even the control. Two of the petri dishes did have colonies but only had 1 each which was most likely contamination rather than B. subtilis based on the look of the colonies which was a semi large almost clear colony vs the small white colonies expected. Team Orion concluded that the method used to culture the bacteria was not at fault since it was the same standard procedure used by the lab biologist and when a test culture was done two weeks prior the bacteria grew just fine. After consulting the labs biologist it was concluded that the two colonies seen were some contaminate and that the B. subtilis had died before it even went into the BalloonSat since the control also had no colonies.

If Team Orion had more funding and time the B. subtilis would be reordered and cultured again. From there a culture would be made each day to determine the exact lifespan of B. subtilis in the lab which is predicted to be just under 14 days. Equipped with this knowledge a new sample of B. subtilis could be ordered sooner so the flight and
incubation would be done well before the calculated lab lifespan of the B. subtilis. This procedure, if funding and time allowed, would repeat the failure and give us the lab lifespan and then fix the failure because a new set of bacteria would be flown before this lifespan.

Error Status: Not fixed

10.0 Ready for Flight

After the first flight Team Orion identified some major problems with the power supply in Project Invictus. Both Arduinos failed due to faulty connections in the power supply. In order to fix these problems weak connections were secured with hot glue and battery connections were tightened to prevent breakage in the power supply for a second flight. Another major error was in the experimental portion of the flight, the B. subtilis ended up not lasting until the flight date and died before launch. In order to solve this Team Orion wants to calculate the lab lifespan of the bacteria and then fly the next set of bacteria within this time frame in order to obtain actual results. To solve the Geiger counter failure simply "turn on Geiger counter" was added to the preflight checklist.

To test these fixes the team went through the checklist the team made to make sure everything was covered and then tugged at the wires some to make sure they stayed secured and did not break. The battery connection was also pulled on to make sure it didn't come apart. Ideally new B. subtilis would be ordered and the lifespan would be calculated, unfortunately this is not possible due to lack of funds and time.

Overall the BalloonSat structure was in good shape and can be reused without any major repairs. Aside from the fixtures mentioned above the BalloonSat needed the camera reattached to the box. This was not considered a failure since it came detached during landing, this is known because all the pictures taken during the flight before the camera died were of the outside of the box. An extra temperature sensor in the external compartment of the BalloonSat had to be moved also. It came to the teams attention during data analysis that the optional temperature probe was only about 2 cm away from a heater block on the other side of the foamcore wall creating higher than normal temperature readings in the outside compartment rendering the data useless. The last thing done with the BalloonSat was wiping the data from all SD cards and changing/charging the batteries.

The BalloonSat can very easily be stored for 6 months until the next flight as long as the batteries are disconnected from the power supplies. In addition bacteria would have to be ordered less than 2 weeks before the launch date and prepped for flight.

In order to activate the payload, the five 9V batteries and the camera battery
would have to be attached. The bacteria has to be put in the BalloonSat and the pressurized containers would have to be sealed. Afterwards, the Geiger counter itself has to be turned on and the BalloonSat sealed. From the outside, the three switches have to be turned on which will be confirmed by the glowing led lights. Then, the camera would be turned on by sticking tweezers in a hole from outside the box which is confirmed by the lense extending.

11.0 Lessons Learned

Over the semester Team Orion encountered many problems and errors that were learned from. Each team member came up with one lesson learned that they would like to pass on.

- Create a better pre-check-in checklist to ensure everything is fully functional during flight
- Make sure all of the wires are strongly soldered
- Better securing on the camera from moving during burst/landing
- Calibrated the Geiger counter before flight
- Dress up for the first presentation
- Space inside box was limited and difficult to work with, get placement of hardware done with construction of box
- Have more meetings and space out the workload instead of doing it all last minute.
- Doing things earlier is better than doing them later

12.0 Message to Next semester

After completion of the semester each team member came up with one point they would like to pass on to the future Gateway to Space students.

- Nail the Proposal and Conceptual Design Review from the start
- Meet up at least two or three time a week
- Start a group text, email, facetime, skype, etc...
- Make sure you get all the stuff turned in on time (Don’t turn anything in late)
- Start building box early! ASAP!
- Keep your batteries as warm as possible during flight! Seriously!
- Predetermine where everything inside the box will go so it’s not crammed inside.
- Find good resources to use (professors, labs etc.) within the CU community to assist you, especially if you are doing a biological experiment
- Think outside the box, try to have original ideas for your satellite
- Be prepared to spend more time outside of the classroom than in it.
- Be a step ahead at all times.
References

1.0 Mission Overview:


7.0 Expected Results: