Colorado Space Grant Consortium

GATEWAY TO SPACE
FALL 2016
DESIGN DOCUMENT

Team 1, Starfleet

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J.R. Greenwalt, Julian Jurkoic, Alex Paquin, Micah Zhang

October 11, 2016
Revision A/B

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date</th>
</tr>
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<td>2016</td>
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<td>1st Draft: Dec 03, 2016</td>
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1.0 Mission Overview

1.1 Mission Statement

Team Starfleet’s primary mission objective is to safely send a balloon satellite to a maximum approximate altitude of 30 km in order to test for the presence of Chlorophyll A producing organisms, specifically algal and planktonic ones, beginning at an altitude of 3 km above the launch site. The mission shall be deemed successful if all mechanical tasks are executed properly, the biological sensor runs and collects data, the satellite returns safely to Earth for further data analysis, and all requirements for the ASEN 1400 course are met.

1.2 Mission Overview

Only within the past century have different kinds of craft begun passing through and out of Earth’s atmosphere to explore other celestial bodies. This means that during the time that these craft have been used to explore bodies aside from Earth, they have potentially been unknowingly picking up contaminants along the journey through the atmosphere and depositing them onto other surfaces within the solar system, or beyond. It is tough to say at this point in time whether or not the current decontamination methods for all spacecraft are thorough enough to prevent interplanetary biological transfers that cannot be detected from Earth. This is a serious issue, and there are international laws set forth by the Outer Space Treaty. This Document clearly states that, “States shall avoid harmful contamination of space and celestial bodies.” Any contamination should be deemed harmful.

The interest in conducting research on this topic is being fueled by intriguing yet unconfirmed reports of live algae being found on the exterior of the International Space Station during a spacewalk. Russian scientists working on the international space laboratory say the sample is believed to have been “uplifted” there by atmospheric currents, however there has been no official confirmation of the discovery by NASA, therefore there has neither been any satisfactory research on a potential deposit method.

However, current scientific research shows that there is actually a large number of bacterial microorganisms living within the range of eight and fifteen kilometers above Earth’s surface. Many of these microorganisms are similar to aquatic bacteria, and are

Commented [AB2]: Best to show picture of the algae, the specimen you are looking for. Make sure to mention each figure in text and say what it is

Commented [AB3]: Need an additional paragraph stating what exactly you expect to happen and what to prove with that


resistant to many of the harsh conditions present near the Tropopause. Because of the reports concerning the International Space Station, combined with the presence of bacterial organisms on the way to the altitude to be researched by the balloon satellite, team Starfleet believes that it is very plausible for other organisms to live in the upper atmosphere and to be carried into space either by air current, or by direct contact from a spacecraft.

To test for the presence of these microorganisms, the balloon satellite shall use an air filter housed within a passive air intake tube to capture particles that are within the range of typical sizes of the organisms being searched for. Furthermore, a specially designed mechanism shall be necessary in order to prevent contamination below 3 km above the surface of the launch site. It can then be determined whether these organisms are actually present or not by using a sensor to test for the presence of Chlorophyll A within the filter and correlate this data to altitude. This sensor shall use an LED (LED430L) mounted to shine inside the tube to excite any Chlorophyll A on the air filter. The Chlorophyll A shall then fluoresce light which shall be gathered through a convex lens and be passed through a red filter and into a photodiode (FDS100), from which the output is generated. If the microorganisms are present, this shall create a brand new issue concerning interplanetary contamination that no aerospace engineer nor scientist has been fully aware of ever before.

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This is an important aspect of space travel that seems as if it may be overlooked today; The assumption that the vacuum of space and the conditions of the atmosphere can safely sterilize spacecraft needs to be validated in order to prevent unforeseen disasters in the future. Team Starfleet believes that researching this topic may help future space missions to come by contributing to a better understanding of the biological makeup of the atmosphere, and the endurance capabilities of the microorganisms being researched.

2.0 **Requirements Flow Down**

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<td>The mission shall fly to an approximate altitude of 30km</td>
<td>Mission Statement</td>
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<tr>
<td>0.1</td>
<td>The BalloonSat shall fulfill all of the all requirements for the ASEN 1400 course.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.2</td>
<td>The BalloonSat shall test for the presence of Chlorophyll A producing organisms, specifically algal and planktonic ones.</td>
<td>Mission Statement</td>
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<tr>
<td>0.3</td>
<td>The total weight of the satellite shall be 964 grams or less and a total budget of $180 or less</td>
<td>RFP</td>
</tr>
<tr>
<td>0.4</td>
<td>The BalloonSat Shall be able to fly again after it’s mission.</td>
<td>RFP</td>
</tr>
<tr>
<td>0.5</td>
<td>The BalloonSat shall record video for the duration of the flight.</td>
<td>RFP</td>
</tr>
<tr>
<td>0.6</td>
<td>Internal temp shall remain above -10°C</td>
<td>RFP</td>
</tr>
<tr>
<td>1.0</td>
<td>A flight string shall be attached through the center of the BalloonSat 0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1.1</td>
<td>A helium weather balloon shall be attached to the flight string.</td>
<td>0.0</td>
</tr>
<tr>
<td>1.2</td>
<td>Sensors for pressure, humidity, internal temperature, external temperature, acceleration shall be flown and data shall be collected and recorded from them 0.1</td>
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</tr>
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<td>1.3</td>
<td>Data from the sensors shall be analyzed 0.1</td>
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</tr>
<tr>
<td>1.4</td>
<td>A sensor to measure chlorophyll shall be flown</td>
<td>0.2</td>
</tr>
<tr>
<td>1.5</td>
<td>The Chlorophyll sensor shall run and data shall be collected from 3100m until 30 km 0.2</td>
<td>0.2</td>
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Commented [AB4]: Separate level 0 and 1 into their own tables for clarity

Commented [AB5]: You can combine some of your level 0. Come to office hours for more information

Commented [AB6]: Not really needed

Commented [AB7]: Should all be from Mission Statement

Commented [AB8]: Not level 1, level 2

Commented [AB9]: Good linkages
1.6 Data collected from the sensor shall be analyzed post flight.

1.7 A budget of mass and money shall be kept and the balloonsat shall be massed before the flight and shall not exceed 964 g in weight.

1.8 The Balloon Sat shall be tested and built to withstand forces incurred upon it during the flight including acceleration on descent, impact with the ground, and possible dragging along the ground.

1.9 A camera shall be flown and photos and or videos which shall be collected.

1.1A The balloonsat shall be insulated and heated sufficiently in order to keep internal temperatures over 10°C

3.0 Design

3.1 Structure

The structure of the Balloon Sat shall be designed to provide support and thermal protection for the payload. We shall insulate the foam core using the foam insulation as a way to thermally protect it. We have also added additional insulation around the 3D printed air filter to protect the inside components from the cold air that will be rushing through the air filter. The main structure of the Balloon Sat shall be constructed of foam core, and shall be a rectangular prism, with a height of 7.5 centimeters and four sides of 18 centimeters. The satellite structure shall be constructed solely from provided materials: no additional purchases shall occur with regard to this aspect of the satellite design. For the purposes of this document, the wall with the switches and LEDs shall be the front wall. The flight string shall be fed through the flight tube in the center of the Balloon Sat. Arduino 1 shall reside against the back left wall of the Balloon Sat and Arduino 2 will be at the back right. The air filter tube of the Chlorophyll A detector shall extend from the top of the structure, to the bottom. Holes of diameter 4 centimeters shall be created on the top and bottom of the Balloon Sat directly above and below the filter. Connected to the top of the filter shall be a funnel with the purposes of optimizing the air intake. In the bottom half of the air filter, layers of black cloth shall prevent light from entering in. The Chlorophyll A sensor shall be positioned along the walls of the air filter tube, pointing towards the filter. Above the Chlorophyll A sensor, shall be a photocell pointed towards the opening of the air filter tube with the purpose of determining the amount of light entering. The amount of light entering the filter tube calibrates the cap open and cap closed positions. The batteries for the heating system and the Arduinos shall be located along the front wall behind the switches, and the heater shall be placed directly south west of the flight tube. The gopro shall be installed at the front left wall, with the lens of the camera extending out of the satellite interior through a hole of...
diameter 2.7 centimeters. The wall closest to the 3D printed air tube will host the external temperature sensor.
A cover hatch for the filter tube shall be operated using a servo, two gears, a drive shaft, two auxiliary shafts, two main sprockets, two auxiliary sprockets, and bearings for all shafts. The servo shall be mounted inside a metal enclosure and directly connected to a small acetyl gear, which is thereby connected to a larger acetyl gear (achieving a 5:1 torque ratio, boosting the motors max torque to 2.3 Nm) mounted on the drive shaft also mounted on the enclosure at one end. From there, the drive shaft connects to a plastic sprocket and chain system which transfers the power of the drive shaft to each of the auxiliary shafts. The auxiliary shafts are directly attached to each lid which when spun shall turn it parallel to airflow (as opposed to perpendicular) allowing the air to flow through.
The Chlorophyll A sensor shall use an LED with a specific wavelength of 425 nm to excite any potential chlorophyll on the filter. The chlorophyll shall have a maximum emission wavelength of 685 nm. The specific red filter within the photodiode housing allows for spectral acceptance of 625 nm up to 750 nm. This sensor shall be required because it is the main component for our mission and is vital to determining success or failure overall.
3.2 Functional Block Diagram

This Functional Block Diagram separates the components of the BalloonSat into 4 systems based on form and function. System 1 consists of hardware components that are critical to the main experiment. These components include: two 9 Volt batteries, one switch, one LED, one Arduino Uno (“Arduino 1”), one 4 GB SD Card, one altimeter, one motor, one chlorophyll sensor system and one photocell system to successfully calibrate and open the cap. The two 9 Volt batteries shall provide power to the switch, which allows the team to turn on Arduino 1. Once Arduino 1 is receiving power, it shall automatically turn on an LED in order to provide visual confirmation to the team that Arduino is on and functioning properly. Arduino 1 shall then provide power to the altimeter, the filter motor, and the chlorophyll sensor system. Out of these three components, the altimeter and the chlorophyll sensor system shall return data to Arduino 1. This data shall then be stored inside the 4GB SD Card. Note that these three components are heavily dependent on each other. The opening of the filter motor is dependent on the altitude measured by the altimeter. The chlorophyll sensor cannot begin to measure the amount of algae that has been collected until the filter is open.

System 2 consists of hardware components that are not critical to the main experiment. These components are: two 9 Volt batteries, one switch, one LED, one Arduino Uno (“Arduino 2”), one 4 GB SD Card, one internal temperature sensor, one external temperature sensor, one pressure sensor, one accelerometer, and one humidity sensor. Arduino 2 shall then provide power to the filter motor, which shall open the cap. Once the cap is open, the chlorophyll sensor shall begin to measure the amount of algae that has been collected. This data shall then be stored inside the 4GB SD Card. Note that these two components are not dependent on each other. The opening of the filter motor is independent of the amount of algae that has been collected.

System 3 consists of hardware components that are not critical to the main experiment. These components are: two 9 Volt batteries, one switch, one LED, one Arduino Uno (“Arduino 3”), one 4 GB SD Card, one camera, and one heater. Arduino 3 shall then provide power to the camera, which shall capture images of the experiment. This data shall then be stored inside the 4GB SD Card. Note that these two components are not dependent on each other. The opening of the filter motor is independent of the amount of algae that has been collected.

System 4 consists of hardware components that are not critical to the main experiment. These components are: lithium-ion battery, one switch, one LED, one Arduino Uno (“Arduino 4”), one 4 GB SD Card, one camera, and one heater. Arduino 4 shall then provide power to the camera, which shall capture images of the experiment. This data shall then be stored inside the 4GB SD Card. Note that these two components are not dependent on each other. The opening of the filter motor is independent of the amount of algae that has been collected.
Arduino Uno ("Arduino 2"), a 4GB SD Card, one internal temperature sensor, one external temperature sensor, one pressure sensor, an accelerometer, and one humidity sensor. The two 9 Volt batteries shall provide power to the switch, which allows the team to turn on Arduino 2. Once Arduino 2 is receiving power, it shall supply power to the LED, giving visual confirmation to the team that Arduino 2 is on and working properly. Arduino 2 shall then provide power to and receive data from the each of the five sensors. This data shall then be stored inside the 4GB SD card. Note that these sensors function independently from one another and only engage in one-way communication.

System 3 consists of hardware components essential to providing heat to the craft. These include: three 9 Volt batteries, one switch, one LED, and one heater. The three 9 Volt batteries shall provide power to the switch. The switch shall provide power to both the LED and the heater. The LED shall provide visual confirmation that the heating unit is receiving power and functioning properly. The heating unit shall then provide heat in order to keep the spacecraft components functional within the optimal operational temperature zone. Note that none of the components of System 3 collect and return data. In other words, they only engage in one-way communication.

System 4 consists of all hardware components that are essential to the operation of the GoPro that shall be placed aboard the spacecraft. It consists of: a lithium-ion battery, a GoPro, and a 4GB SD card. The lithium-ion battery shall provide power to the camera. The camera shall take pictures and record video throughout the duration of the flight. This data shall then be stored inside the 4GB SD card located inside the camera. Note that while System 4 does collect data. It does not return data in the form of two-way communication.

### 3.3 Concept of Operations

Project Genesis shall send a BalloonSat equipped with electronic sensors to an altitude of 30 km in order to test for Chlorophyll A producing organisms. In order to achieve this mission, the team shall ensure the entire structure has been built properly before launch day. On launch day, the team shall initialize all powered components within the satellite before send-off. During ascent, the hatch mechanism shall activate at the designated altitude of 3100 meters and the sensor inside shall begin collecting data. At the highest altitude, 30 km, the weather balloon shall burst, sending the satellite back to Earth. The sensors inside shall continue to collect data, however the biological sensor shall cease activity once burst has occurred. The team shall then recover the BalloonSat from the landing site, take pictures of its condition and turn off all switches.

To retrieve data from the satellite, the following sequence of events shall be executed following both the team’s arrival at the landing site as well as after each test. The BalloonSat shall be deactivated by turning each switch to the off position. After disconnecting from the flight string, the satellite shall be opened and the SD cards shall be retrieved one at a time and placed in labeled containers that describe the data stored on them. Having predetermined the locations that each sensor writes to in each SD card, data shall be transferred onto team member’s laptops, and the known conversion factors shall
be applied to each data set in order to obtain the appropriate data feed and then will be plotted. The camera footage shall be transferred similarly, and analyzed for items of note.

The design of the BalloonSat fulfills all requirements set forth by the ASEN 1400 course regarding structure, software, and electrical layout. The satellite shall be attached to a balloon with a string running through a flight tube through the center of the structure. As shown in the budget section the BalloonSat shall meet both the weight and monetary requirements as required by the request for proposal. Contact information and an American flag shall be visible on the outside of the BalloonSat. The structure shall allow for a hole in the side for the camera to take pictures and video on the outside. The heater and insulation shall keep the components above -10 degrees Celsius during flight. Project Genesis’s BalloonSat shall allow for enough room for the air filter and fluorometer to collect enough data during flight. External and internal temperature sensors, pressure, humidity, and a 3-axis accelerometer shall also be flown and collecting data throughout the entire flight. The sensors shall collect data and store the information on the SD card.

4.0 Management

Team Starfleet has been divided into four main subsystems: Structures & Thermal because these go hand in hand, C&DH, Software & Power, for the same reason, Science, because this is the most important aspect of the mission and is a large task in and of itself, and finally Budget & Imaging in order to also allow the budgeting team to have a hands on role in the mission. However, some team members have roles that may tie into two different subsystems. The team is focused on staying organized and on task, and has therefore mapped out the schedule, detailed below.
4.1 Team Organization

<table>
<thead>
<tr>
<th>Name</th>
<th>Contact</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samuel Sawyer</td>
<td><a href="mailto:Samuel.sawyer@colorado.edu">Samuel.sawyer@colorado.edu</a></td>
<td><strong>Team Leader</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Science Team Leader</td>
</tr>
<tr>
<td>MacKenzie Lobato</td>
<td><a href="mailto:MacKenzie.lobato@colorado.edu">MacKenzie.lobato@colorado.edu</a></td>
<td><strong>Team Co-Leader</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C&amp;DH, Software &amp; Power Budget &amp; Imaging</td>
</tr>
<tr>
<td>Colin Claytor</td>
<td><a href="mailto:Colin.claytor@colorado.edu">Colin.claytor@colorado.edu</a></td>
<td>Structures Sub-Leader</td>
</tr>
<tr>
<td>John Greenwalt</td>
<td><a href="mailto:John.greenwalt@colorado.edu">John.greenwalt@colorado.edu</a></td>
<td>Budget &amp; Imaging Team Leader</td>
</tr>
<tr>
<td>Julian Jurkoic</td>
<td><a href="mailto:Julian.jurkoic@colorado.edu">Julian.jurkoic@colorado.edu</a></td>
<td>Structures &amp; Power</td>
</tr>
<tr>
<td>Alexandra Paquin</td>
<td><a href="mailto:Alexandra.paquin@colorado.edu">Alexandra.paquin@colorado.edu</a></td>
<td>C&amp;DH, Thermal Sub-Leader</td>
</tr>
<tr>
<td>Rachel Adelberg</td>
<td><a href="mailto:Rachel.adelberg@colorado.edu">Rachel.adelberg@colorado.edu</a></td>
<td>Science</td>
</tr>
<tr>
<td>Micah Zhang</td>
<td><a href="mailto:Tizh7831@colorado.edu">Tizh7831@colorado.edu</a></td>
<td>C&amp;DH, Software &amp; Power Team Leader</td>
</tr>
</tbody>
</table>

4.2 Schedule

Team Starfleet will meet in the Brackett common room on Sundays from 7:30-10:00 p.m., Tuesdays from 7:30-9:30 p.m., and Thursdays from 10:45 a.m. to 12:00 p.m. Other meetings will be scheduled on an as needed basis if we start to fall behind on the project.

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<th>Subsystems</th>
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<tr>
<td>Sep 11-18</td>
<td>Write Proposal (Due 9/19)</td>
<td>All Team Members</td>
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<tr>
<td></td>
<td>HW #5 (Due 9/15)</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td>Make final decisions on parts</td>
<td>Structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Science</td>
</tr>
<tr>
<td>Sep 19-25</td>
<td>Order Parts (9/19)</td>
<td>Thermal</td>
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<tr>
<td>Oct 11th, 2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td></td>
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| **Proposal (Due 8 am 9/19)**  
| HW #7 (Assigned 9/20)  
| HW #8 (Assigned 9/22)  
| HW #6 (Due 9/22)  
| ATP - by appt.  
| Begin building structure  
| Elementary coding | **Structures**  
| **Electrical**  
| **Software** |
| **DD Rev A/B (assigned 9/27)**  
| HW #7 (Due 9/27)  
| HW #8 (Due 9/29)  
| Continue building structure  
| Begin building fluorometer  
| Elementary Coding | **Electrical**  
| **Structures** |
| **Oct 3 - 9**  
| PDR Presentation (10/6)  
| DD Rev C (assigned 10/6)  
| Finish Building Structure (10/9)  
| Finish building fluorometer  
| Start Testing (Drop/Stair Pitch Test) | **All Team Members**  
| **Structures**  
| **Science** |
| **DD Rev A/B (Due 10/11)**  
| Mid-Sem. Team Evals (assigned 10/13)  
| Calibrations/Programming  
| Testing (Whip)  
| Rebuild | **Software**  
| **Science** |
| **Oct 17 - 23**  
| Mid-Sem. Team Evals (Due 10/18)  
| Service Approvals (Due 10/20)  
| Calibrations/Programming  
| Testing (Cooler)  
| Rebuild | **Structures**  
| **Software**  
| **Science** |
| **Oct 24 - 30**  
| RFF Cards (assigned 10/25)  
| Finish Calibrations/All Arduino programming  
| Finish Building  
| Final Testing | **All Team Members** |
| **Oct 31 - Nov 6**  
| HW #9 (Due 11/1)  
| In Class Simulation (11/3) | **All Team Members** |
| **Nov 7 - 12**  
| LRR Presentation (11/8)  
| DD Rev C (Due 11/10)  
| Final Weigh-in and Turn In by apt. (11/11) | **All Team Members**  
| **Science** | **DD Rev D (Assigned 11/15) Members**  
| **Post Launch**  
| **Science** | **Rev A/B** |
5.0 Budget

Team Starfleet’s final weight ended up well below the revised weight limit of 964 g, and even with last minute additions and expedited shipping, the total budget remains below the requirement of $180.00. The cost of dry ice is not included in the total cost.

<table>
<thead>
<tr>
<th>Item</th>
<th>Count</th>
<th>Source</th>
<th>Weight</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
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<td>COSGC</td>
<td>46.71 g</td>
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<tr>
<td>GoPro</td>
<td>1</td>
<td>J.R.’s Sweet Mother</td>
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</tr>
<tr>
<td>MicroSD Cards</td>
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<td>COSGC</td>
<td>0.5 g</td>
<td>Provided</td>
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<tr>
<td>Arduino Uno 2 w/ MicroSD Shield &amp; Balloon Shield</td>
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<td>COSGC</td>
<td>67.09 g</td>
<td>Provided</td>
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<td>COSGC</td>
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<td>Heater Kit</td>
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<td>COSGC</td>
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<td>Flight Tube</td>
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<td>Paper Clips</td>
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<td>COSGC</td>
<td>5.0</td>
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<td>Washers</td>
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<td>COSGC</td>
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<tr>
<td>Blue LED (LED420L)</td>
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<td>ThorLabs</td>
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### 6.0 Test Plan and Results:

#### 6.1 Safety

Team Starfleet is committed to keeping each team member safe from any possible injuries that could be sustained during the project. To keep that from happening, the team shall be wearing safety goggles when any machining or soldering is being done or gloves when using dry ice. In addition, each test shall be done in a safe manner with multiple team members present. For each test, the team shall make sure the area is cleared of anyone or anything within close proximity to the test site including away from any windows that could potentially break. The team shall also seek help and ask questions...
when handling dry ice or any other heavy machining needs to be done.

6.2 Test Plan

6.2.1 Structural Testing

The purpose of structural testing is for team Starfleet to test the structural integrity of the satellite through simulations of the launch, flight, burst, and drop. The goal is to decrease the likelihood of violent external environments causing the internal components of the satellite to dismount as well as break.

6.2.1.1 Whip Test

On October 10th and October 17th the whip test was performed on Farrand Field. Bars of soap enclosed in a sock were added to the box to equal the real mass of the components during the test. The satellite was connected to a flight cord strung through the center tube and was spun overhead by four team members. By slowly accelerating the angular velocity, members of Team Starfleet spun the satellite, while rapidly changing directions for 30 seconds each trial.

The whip test allows Team Starfleet to simulate the satellite being whipped by the winds during ascent, the shock of the burst, and the high G forces during descent. After the four trials, the team assessed the damages and continued on to the drop test.

Safety Note: When performing the Whip test, Team Starfleet made sure that a safe perimeter had been created safely away from any pedestrians, windows, or anything else the satellite could damage should it release from the flight string. The test was also performed at a time where pedestrian traffic was low.

6.2.1.2 Drop Test

On October 10th and October 17th the drop test was performed off the bridge between the Integrated Teaching and Learning Laboratory and the Discovery Learning Center. Bars of soap enclosed in a sock were added to the box to equal the real mass of the components during the test. The structure was dropped five times onto the concrete surface.

The drop test allows Team Starfleet to simulate the many ways in which the satellite could land on its edges, corners, or sides when it drops after the balloon pops. Since the satellite lands on concrete, the drop test also simulates the satellite landing on an extremely dense surface. After the five trials, the team assessed the damages and continued to the stair test.

Safety Note: Before performing the Drop Test, Team Starfleet made sure that a safe perimeter had been created around the drop zone to make sure no pedestrians were hit. The test was also performed at a time where pedestrian traffic was low.
6.2.1.3 Stair Test

On October 10th and October 17th the stair test was performed down the stairs in the Discovery Learning Center. Bars of soap enclosed in a sock were added to the box to equal the real mass of the components during the test. The structure was rolled, kicked, and dropped down the stairs in the Discovery Learning Center five times by multiple team members.

The stair test allowed Team Starfleet to simulate the vigorous behaviors the satellite endures after the drop, as the satellite drags, rolls, and bounces. After the five trials, the team assessed the damages and continued accordingly by designing the second revision of the structure.

Safety Note: A safe perimeter was created around the final landing zone, as well as flight path, to make sure no pedestrians were hit. The test was also performed at a time when pedestrian traffic was low.

6.2.2 Experimental Testing

The purpose of experimental testing is for team Starfleet to test all of the experimental components of the satellite. The goal is to make sure the In-Situ sensor, the photocell, the passive air intake tube, the filter, the funnel, and the filter cap are working appropriately to their functions, as well as decrease the likelihood of any risks occurring that would complicate the mission’s results.

6.2.2.1 Chlorophyll Test

Team Starfleet shall use a sample of common Spinach to see if the In-Situ sensor is capable of performing its duty of detecting Chlorophyll A. The team shall also use other substance(s) that don’t contain Chlorophyll A to make sure the sensor is picking up the correct data. This test shall be completed once the sensor has been constructed, and code has been written for it, or on October 23rd.

6.2.2.2 Fluorometer Calibration Test

Once the In-Situ fluorometer is confirmed to be detecting traces of Chlorophyll A in the filter, Team Starfleet shall use a fluorometer on East Campus with Annette Erbst to calibrate the results being output by the sensor. It is important to make sure that the sensor is calibrated correctly, otherwise data shall not be sufficiently collected. The team shall aim to calibrate the sensor to a relatively small percentage of error. This test shall be completed once the sensor has been constructed, and code has been written for it, on October 23rd.

6.2.2.3 Photocell Test for Cap Calibration

[Commented [AB13]: Need small paragraph on how you will take data off and analyze it]

[Commented [AB14]: Never said how exactly you tested this with altitude, what you really did]
Making sure the Filter Cap stops at the correct open and close positions is vital to ensuring the coordination of the science subsystems. The filter cap mechanism is triggered by the payload reaching a specific altitude. Once the specified altitude is reached, the cap calibrates the open and closed positions based on the air filter tubes light intake. When the photocell reads that the light intake is at a maximum, the servo stops turning the cap and remains in the cap open position. When light intake is a minimum, the servo stops turning the cap and remains in the cap close position. For the purposes of our mission, the cap will alternate between the cap open and cap closed positions. Cap open allows air collection samples to flow into the air filter tube and cap close allows for the fluorometer to take measurements.

6.2.3 Mission Simulation Testing

The purpose of Mission Simulation testing is for Team Starfleet to make sure the satellite is capable of performing all of its duties throughout the entire duration of the flight. The goal is for the satellite’s internal components to work together properly and reliably for the entire duration of the flight.

6.2.3.1 Dry Simulation Test

To make sure the internal components are capable of working for the entire duration of the flight on launch day, the satellite shall be placed in a room, turned on, and run for 90 minutes. After the 90 minutes, the team shall analyze the data stored in the SD cards and look for any complications that occurred throughout the test. If any complications did occur, the test shall be redone until all complications are resolved. The dry test shall be performed successfully once in order to ensure the systems reliability. The dry test shall be performed once all structural, experimental, functional, and camera testing has been done.

6.2.3.2 Cold Test

During the flight, the satellite should experience extremely cold temperatures, specifically in the tropopause, of approximately -60 degrees Celsius. The internal temperature of the satellite must not drop below -10 degrees during, otherwise the electronic components shall become highly likely to fail. The cold test shall simulate the capabilities of the heater in maintaining an internal temperature with -10 degrees Celsius as an absolute minimum, while ensuring the rest of the satellite’s components are working properly.

For the Cold test, the satellite shall be sealed, activated, and placed in a cooler. Directly before the cooler is sealed, two pieces of dry ice that are blocked by cardboard and surround the satellite shall be added. The test shall last 60 minutes, to simulate an
exaggerated duration of the flight. All of the sensors shall run and record data for the entirety of the test, to make sure the batteries remain fully functional. If any internal components malfunction during the test, the team shall apply the proper adjustments, and redo the test until all interior components are capable functioning at the temperature of dry ice, or -78.5°C. This test shall be performed once all structural, experimental, functional, camera, and dry testing has been done, or on October 25th.

*Safety Note: All team members performing the cold test shall wear gloves. Any members nearby that do not touch the dry ice shall stand at a safe distance away to prevent injury.*

### 6.2.4 Subsystem/Environmental Testing

Each one of our standard package of sensors shall be carefully tested to ensure that they will maintain their functionality throughout the entirety of the flight.

#### 6.2.4.1 and 6.2.4.2 Internal and External Temperature Sensors

The internal and external temperature sensor shall be tested by moving the BalloonSat inside and outside of a residence hall at night so we can have a more obvious difference in temperature to make sure our temperature sensors work.

#### 6.2.4.3 Pressure Sensor

The pressure sensor shall be tested by driving up flagstaff road in Boulder, CO and comparing the value to the National Center for Atmospheric Research’s reading at their altitude. After that we shall compare the readings and confirm they are accurate.

#### 6.2.4.4 Humidity Sensor

The humidity sensor shall be tested along with the temperature sensor. It shall stay inside and gain readings and then be taken outside to obtain an accurate reading of the humidity outside vs. inside. This shall be done multiple times to obtain an accurate measure of fluctuations in inside humidity versus outside humidity.

#### 6.2.4.5 Accelerometer

The accelerometer shall be tested by taking readings while it is stationary and then while also being moved in multiple directions on the x and z-axis to prove that our accelerometer does in fact obtain accurate readings.

#### 6.2.4.6 Camera Testing

The GoPro camera shall be tested by taking preliminary pictures and videos of team meetings and also being left on to ensure there is enough battery life to endure most, if not the entire length of the flight.

### 6.3 Test Results

#### 6.3.1 Structural Testing

#### 6.3.1.1 Whip Test Results
The first and second whip test demonstrated that the flight tube assembly was performed properly. The craft was whipped as designed by the test and withstood the forces of the test. This test caused the least damage.

6.3.1.2 Drop Test Results

The first drop test demonstrated that the second revision of the structure requires stronger joints, more properly sealed folds, and a larger amount of metal reinforcement tape on the corners and edges. This test caused significant damage that was less than that of the stair test. The second drop test with our second revision of the structure was successful as there were only minor indents on the corners.
6.3.1.3 Stair Test Results

The first drop test demonstrated that the second revision of the structure requires stronger joints, more properly sealed folds, and a larger amount of metal reinforcement tape on the corners and edges. This test caused the most damage. The second stair test with our second revision of the structure was successful as there were only minor indents on the corners.
6.3.2 Sensor Test Results

6.3.2.1 Internal Temperature Sensor Results

The internal temperature probe was tested by transferring it into and out of a heated building on a cold night. Large fluctuations in the recorded temperatures of the internal temperature probe were induced through this process, and obtained data that confirmed that the probe was functional, and calibrated. (Graph below)

6.3.2.2 External Temperature Sensor Results

The external temperature probe was tested at the same time as the internal temperature probe, in the same manner. The external probe was warmed by hand as the test proceeded in order to differentiate it from the internal temperature data. (Graph below)
6.3.2.3 Pressure Sensor Results

The pressure data was tested by using the National Center for Atmospheric Research’s (NCAR) barometric readings at their altitude level and then Team Starfleet shall drive up Flagstaff road and once they reach the same altitude as NCAR, they shall be able to compare their readings to that of NCAR’s reading and confirm that our pressure sensor does work and can detect that pressure decreases as altitude increases. Because of the unique pressure sensor calibration of Team Starfleet’s experimental payload, the results displayed are specifically for the fluorometer activation sequence.

Commented [AB22]: need to mention what NCAR said the pressure was and prove to me your data was correct
6.3.2.4 Humidity Sensor Results

The humidity sensor was exposed to a variety of different environments of verifiable humidity, such as the interior of a recently used washing machine, and the immediate surroundings of a pond. Considerable changes were observed in the humidity data, which demonstrated that the sensor was functional.
6.3.2.5 Accelerometer Results

The accelerometer was vigorously shaken, and taken on a run. After the run, the testers briefly rested, causing the data to even out. Towards the end, three different rapid accelerations were applied to the sensor assembly, which were observed within the data that was collected.
6.3.2.6 Cold Test Results

The GoPro test was successful and was able to take multiple pictures and videos in high quality as well as withstand extreme cold temperatures.

7.0 Expected Results

7.1 Chlorophyll A

Team Starfleet expects to find data on Chlorophyll A producing organisms at different altitudes in the atmosphere. The Chlorophyll A sensor shall detect how much biomass is present at certain points of the flight. An increase in concentration with an increase in altitude is expected. In a previous test done, scientists at the School of Marine Sciences, University of Maine, were able to successfully build a fluorometer using the same method to be used by the team, below are their results (Figure 1). Team Starfleet’s graph shall be set up in the same way, with the change in Chlorophyll over time, but the data shall increase over time because little to no biological samples shall leave the filter. Team
Starfleet’s expected results for this test is shown in figure 2. This data shall first confirm that there are Chlorophyll A producing organisms in the upper atmosphere, and shall then log at what concentration, and at what height.

Figure 1: Chlorophyll A vs. Time

Figure 2: Expected Concentration (ug/l)
7.2 Sensor Suite
The required sensor suite hardwired to the Balloon Shield is expected to return data similar to Figure 2. Launch occurs at time = 0, Burst at time = 50, and Landing at time = 100.

7.2.1 Pressure
For pressure readings, Team Starfleet expect to see a decrease in pressure throughout the flight, having the pressure steadily approaching 0. This is because there is less air in higher altitudes, which decreases the pressure. During descent, however, pressure shall return back to the levels experienced at launch.
7.2.2 Temperature

The Temperature sensor shall detect a decrease during the flight. While the balloon is in the troposphere it is expected to decrease steadily to about -60 degrees Celsius. Once the balloon reaches the stratosphere, it shall increase to about -40 degrees Celsius and then burst.

The internal temperature shall be 30–40 degrees warmer than the external temperature due to the heater. The internal temperature shall still have the same pattern of the external temperature of decreasing until the stratosphere, and then slowly increasing, but at a warmer temperature.

Commented [AB30]: ozone layer?
7.2.3 Humidity
Team Starfleet expects humidity to decrease as well, and eventually approach 0 throughout the flight. There may be slight increase in humidity in the beginning of the flight, if the satellite were to pass through a cloud.

(Figure 4)
7.2.4 Accelerometer

Team Starfleet expects to see both accelerometers keeping a steady value up until burst. At burst they should accelerate rapidly in both directions, and then go back to the steady value.

![Accelerometer Graph]

8.0 Launch and Recovery

On the day of the launch, Team Starfleet’s members shall meet in the parking lot by the Engineering Center at 4:00 a.m. and drive to the launch site. At arrival, team Starfleet’s BalloonSat shall already be secured with the corners and edges taped sufficiently to withstand the launch, flight, descent, and landing. One team member shall serve as the launcher for Team Starfleet. The team member shall make sure the switches are turned on and the LEDs turn on to indicate everything inside the box is functioning properly. The GoPro shall be turned on using a paperclip poked through a small hole in the BalloonSat. The camera shall beep, alerting Team Starfleet that it is on. The button shall be pressed three more times to put it in video mode, and then the paperclip shall be poked through another small hole in the top of the structure to begin recording.

After launch, all teams shall track their BalloonSats and drive to the landing spot to retrieve it. Team Starfleet shall take pictures of their BalloonSat at the landing spot and compare them with pictures taken of the structure before launch to determine any structural damage. Once back at CU, Team Starfleet shall remove the microSD cards.
from the two Arduinos and the GoPro. The footage from the GoPro microSD and the data from the microSD will be transferred to team Starfleet’s laptops. Team Starfleet shall compare the data from Project Genesis and compare it to the expected data. Team Starfleet shall then classify Project Genesis as a success or a failure. The team shall also gather data showing internal and external temperature, humidity, acceleration, and pressure. This data shall be compared to other team’s data to check for similar results.