It's Always Sunny in Boulder

February 11, 2018
Balloon Satellite Mission Proposal


Commented [TS1]: Nice Proposal overall. Make sure that you check the formatting in Word once you convert it. Also read over your Proposals for grammar and spelling mistakes as you have a few. The mission sounds like a good idea, there will just have to be some thought put into the design of the “sun tracking panels” and then how you will make sure that the comparison test between the panel designs are fair. Remember your project name in the header. Please visit my office hours if you want more feedback.
1.1 Mission Statement

It’s Always Sunny in Boulder, funded by the ASEN 1400 course at the University of Colorado Boulder, will craft a balloon satellite weighing approximately 800g to travel to an altitude of approximately 30,000 meters using a hydrogen weather balloon. The purpose of the experiment is to track the sun using a light sensor, 3-axis gyroscope and photovoltaic cells in addition to providing a source of power to the system with a photovoltaic array around the satellite itself. This experiment will allow the group to identify the efficiency of sun tracking with minimal resources in a chaotic environment versus covering the craft in solar panels in the same situation.

1.2 Mission Overview

The inspiration for this experiment stemmed from the process of gaining solar energy on the International Space Station. Using Solar Alpha Rotary Joints (Alpha Gimbals) and Beta Gimbal Assembly (Beta Gimbals) (Figure 1 shown right)\(^1\), the International Space Station is able to rotate and adjust its Solar Array Wings to provide maximum efficiency and power itself. These wings use the gimbals to orient themselves to always be in a position of direct or as close to direct sunlight as possible. At the beginning of its lifetime, the ISS was able to produce a maximum of about 31 kW, now it can produce a maximum of 26 kW due to aging per set of 4\(^2\). All together the system generates 84 kW to 120 kW of electricity, which is enough to power 40 homes\(^3\). This huge power accumulation is accredited to its ability to track the sun with its gimbaled solar arrays.

It’s Always Sunny In Boulder looked upon this technical marvel and began to compare it to the group’s original idea of creating a box covered in solar panels to power the systems inside. From this, the idea of testing the efficiency of both options became a reality. The team wanted to devote their balloon satellite to comparing the ability of a gimbaled solar panel to receive energy at the same rate that a box covered in panels can, with the deciding factor of comparison being duration of exposure along with cost and surface area being taken into consideration. Taking into account the chaotic nature of the ascent, with rotations and whiplash due to lack of stabilization, the balloon sat will try to accommodate this with the gimbal, using it as a way to accumulate the maximum amount of energy from the solar panel while being whipped around and rotating, while the panels on the outside of the balloon satellite will be stationary, accumulating energy as

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the satellite spins to accommodate for the change in position at which the sun will be shining onto the box. Thus the experiment will test compare the abilities of both arrays to accumulate the most continuous and consistent amount of energy from the given fixtures.

2.0 Technical Overview

Team It’s Always Sunny In Boulder’s satellite will be a hexagonal prism with a base diameter of 30cm and walls with a height of 10cm. A hexagonal shape was chosen to increase the surface area of solar cells facing the sun at a given time. It will be constructed from ⅜” black foam core and held together with aluminum tape and hot glue. A string will run through the center of the top and bottom faces via an internal tube in order to attach the satellite to a balloon. Each wall face will have a small hole in the center, through which will run the wiring for a small solar panel, which will be attached to the outside of each wall. The inside of the satellite will contain all of our electronic components, detailed in section 2.1. The top face will contain a small hole through which will protrude the rotating arm of a servo motor. The bottom face will contain another hole through which a GoPro Hero4 camera will take video of the flight. All holes will be covered from the inside using insulation.

2.1 Structure and Design

Two main systems will be contained within the satellite. The outside will be covered with solar panels, which will be fed to a rechargeable battery. Additionally, an array of 9 volt batteries will provide power to the system, which consists of two Arduino Unos, a balloon shield circuit board, a GoPro Hero4, a servo motor, a single solar cell, and a heater. Using light and heat sensors, the location of the sun will be tracked, and the servo motor will orient the solar cell towards the sun.
2.2 Hardware

Solar panels will be ordered once the permission to proceed is received and output tested using a multimeter from the ITLL. Once the output is known, appropriate current sensors will be ordered and tested using the second Arduino. Solar panels will then be integrated into the main structure, leaving one to be integrated into the sun tracking system. The light sensor will be ordered, and tested using the second Arduino and the sun. The servo will be ordered and tested using the second Arduino. The gyroscope will be ordered and tested using the second Arduino. The light sensor, gyroscope, and servo will then be combined to accurately track the sun. Voltage regulators will be ordered and tested using 9V batteries and the second Arduino. Current sensors and voltage regulators will then be integrated into the solar panel - Arduino circuits.

Commented [TS14]: Consider using an oscilloscope, it is more accurate and a useful skill to have. I can teach you guys if you like.

Commented [TS15]: How are you going to measure the efficiency of sun-tracking panels and "stationary panels" if you are using 8 on the box vs. 1 on the tracker? The way you measure the efficiency of the solar needs to be expanded on and you need to ensure that it is a fair comparison.

Commented [TS16]: Similar to what I said in the previous section. Explain how this will happen.
2.4 Testing

After each test has been performed, it will be confirmed not parts of the structure have broken or malfunctioned before proceeding. In the event of negative test results, changes will be made to the structure to accommodate and eradicate any problems.

2.4.1 Whip Test

Following the burst of the balloon, the satellite will be subjected to large amounts of G force. To simulate this on the ground, the satellite will be attached to a string and swung in circles. This test will take place in a large open area, most likely the Business Field on CU Boulder Campus, away from any people or buildings.

2.4.2 Drop Test

It is expected that the satellite will land on the ground at approximately 30 mph. In order to test for the satellite’s survivability during landing, it will be dropped from a height of approximately 10 meters. This test will be performed from the bridge between the DLC and ITLL on CU Boulder Campus.

2.4.3 Stair Pitch Test

After the satellite has landed, it may be dragged across possibly rough terrain if wind re-inflates the parachute. To simulate this, the satellite will be dropped down a flight of stairs.

2.4.4 Sensor Tests

In order to make sure our solar panels and solar cell are functioning properly, each component will be tested normally on the ground. Data will be collected from the panels to determine the amount of power received and the sun tracking mechanism will be tested in a large open area with no close buildings or sun-blocking objects.

2.4.5 Full Functionality Test

In order to confirm that all components of the satellite function together correctly, a full functionality test will be performed. The system will be on and operational for 3 hours to simulate launch time.

2.4.6 Cooler Test

While travelling through the upper atmosphere, the satellite will experience extremely cold temperatures. In order to ensure each component can survive these conditions, the satellite will be turned on and placed in a cooler with dry ice for 3 hours.

2.5 Safety

Commented [TS17]: Nice
Commented [TS18]: Metric units
Commented [TS19]: Double space
Commented [TS20]: Specify the speed that it will land because you referred to the landing speed at the start
Commented [TS21]: pushes
Commented [TS22]: generated
Commented [TS23]: Spelling
Commented [TS24]: Will the sun tracking system also be tested? If so how?
Commented [TS25]: Nice

As always when designing, constructing, and testing a spacecraft the team must be serious about safety. Team *Always Sunny in Boulder* will be aware of the practical safety guidelines when handling and/or testing all materials that are provided and/or bought. Such measures will be put to practice by assigning a sort of buddy system where the main lead (the team member with the most skill in that area) will not only instruct but take responsibility for safety when other groups members are participating in that skill set. An example, being that when in the Structural team lead will make sure that when handling the laser cutter or box cutters that each member is following the appropriate method of use to avoid serious injury. All team members will, before using any heavy machinery, attend an ITLL workshop for said machinery.

2.6 Data Analysis and Retrieval:

Before the team retrieves the data, it needs to be established in what capacity. They will be responsible for making sure the data runs through the board correctly. Such that when Always Sunny in Boulder sends their BalloonSat up 30km the code can process the data efficiently and there will not be any misreading that will affect the data analysis later on. The sensors and code are an integral part of the science experiment without the proper readings the final presentation will be comprised.

The main technique to retrieving the data will be through the sensors that are provided by COSG (Colorado Space Grant). It is the intention of *Always Sunny in Boulder*’s BalloonSat to compare static solar panels with sun tracking panels. Therefore the datasets the team is most interested in are light intensity, temperature, rotation and power generated.

One of the purposes of the mission is to test how well the solar panels power the systems on our BalloonSat, as well as how the solar tracking system performs. Moreover, it will be beneficial for *Always Sunny in Boulder* to compare their results to those from previous teams; that way real solutions and diagnosis can take place. After all, it is the whole mission of Always Sunny in Boulder to address and provide a solution to the alternative energy for the BalloonSat. For this reason, Always Sunny in Boulder can identify the issues the other teams’ may have. In all, the data is to be presented in a way to provide details on how temperature, pressure, light intensity, and rotation rate affect the BalloonSat’s solar tracking and solar panel performance.

2.7 Functional Block Diagram

Our functional block diagram for our satellite is shown below. A functional block diagram is essentially a design layout that describes the functions and interrelationship of the systems, the systems being the Arduino Unos, heater, and GoPro. The inputs and outputs of blocks that will be wired together are depicted by the lines connecting the components.
By the functional block diagram it is shown that the 9V batteries will be the main power source of the system, but on the second Arduino there will be solar panels in addition to the battery. Another component to note are the LEDs, they are included to visually prove that the power sources are working properly before take off.

3.0 Management and Cost Overview

3.1 Schedule

<table>
<thead>
<tr>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Test: Temperature, Servo, Light, Humidity, Pressure, Gyro, Current</td>
<td>Feb. 19th</td>
</tr>
<tr>
<td>Test structure: the main body Stair Test</td>
<td>Feb 26th</td>
</tr>
<tr>
<td>Whip Test for mechanical instability counterbalance</td>
<td>Feb 27th</td>
</tr>
<tr>
<td>Temperature test: BalloonSat integrity</td>
<td>March 1st</td>
</tr>
<tr>
<td>Solar Panel test: ensure panels are reading data correctly</td>
<td>March 7th</td>
</tr>
<tr>
<td>Preliminary Design Review Presentation</td>
<td>March 6th at 7AM</td>
</tr>
<tr>
<td>BalloonSat passes all tests and is ready for launch</td>
<td>March 22nd</td>
</tr>
<tr>
<td>Launch Readiness Review Presentation</td>
<td>April 4th at 7AM</td>
</tr>
<tr>
<td>All systems go for launch day</td>
<td>April 7th at 6:50 AM Windsor, CO</td>
</tr>
<tr>
<td>Data retrieval for analysis</td>
<td>April 8th</td>
</tr>
<tr>
<td>Quick Look Post Launch Presentation</td>
<td>April 12th at 7AM</td>
</tr>
<tr>
<td>ITLL Design Expo</td>
<td>April 28th 8AM - 1PM</td>
</tr>
</tbody>
</table>


It's Always Sunny in Boulder
3.2 Management and Team Structure

The team leader is in charge of viewing schedules and making sure that the team has meeting times that work. Additionally, the leader must keep the team on track to make sure that the project is finished on time. His job is to keep the team on track for launch day. The budget manager records all of the materials that are needed to complete the project and how much they cost; they are in charge of approving the design and software teams based on the tools at hand. The research team will pull all of the facts that are needed to present our project as one with a good understanding of solar power. With the understanding of solar power and how it will behave in the atmosphere the testing team will know the kinds of conditions that we will be facing when the BalloonSat goes up so they will ensure that the testing is being done in preparation for those kinds of conditions. On design and CAD the team will be using SolidWorks to sketch a design that the whole group wants to move forward with. This will be used by the structure team which will know what to expect moving into the building phase. The structure team will be using the designs made to build the BalloonSat with all of the materials that can be acquired. Finally, the software team will be working with the arduinos by writing the code and attending arduino workshops in the ITLL and the electronics team will be making sure that the code works through arduino software downloaded onto each laptop.

### 3.3 Cost Overview

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Quantity</th>
<th>Source</th>
<th>Price</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Uno</td>
<td>2</td>
<td>COSGC Provided</td>
<td>$50</td>
<td>50</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>2</td>
<td>COSGC Provided</td>
<td>$2</td>
<td>2</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>1</td>
<td>COSGC Provided</td>
<td>$1</td>
<td>1</td>
</tr>
<tr>
<td>Micro SD Card</td>
<td>2</td>
<td>COSGC Provided</td>
<td>$2</td>
<td>2</td>
</tr>
<tr>
<td>Humidity Sensor</td>
<td>1</td>
<td>COSGC Provided</td>
<td>$1</td>
<td>1</td>
</tr>
<tr>
<td>Heater Kit</td>
<td>1</td>
<td>COSGC Provided</td>
<td>$100</td>
<td>100</td>
</tr>
<tr>
<td>Space Grant Shield Kit</td>
<td>2</td>
<td>COSGC Provided</td>
<td>$4</td>
<td>4</td>
</tr>
<tr>
<td>Three Axis Accelerometer</td>
<td>1</td>
<td>COSGC Provided</td>
<td>$1</td>
<td>1</td>
</tr>
<tr>
<td>Half Sheet Black Foam Core</td>
<td>3</td>
<td>COSGC Provided</td>
<td>$120 (40 each)</td>
<td>120</td>
</tr>
<tr>
<td>GoPro Hero4 Session Kit</td>
<td>1</td>
<td>COSGC Provided</td>
<td>$74</td>
<td>74</td>
</tr>
<tr>
<td>OpenLog Data Logger</td>
<td>2</td>
<td>COSGC Provided</td>
<td>$60 (30 each)</td>
<td>60</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>N/A</td>
<td>N/A Provided/$10</td>
<td>$50</td>
<td>50</td>
</tr>
<tr>
<td>Current Sensor</td>
<td>1</td>
<td>Sparkfun</td>
<td>$16 (8 each)</td>
<td>1</td>
</tr>
<tr>
<td>9V Battery</td>
<td>18</td>
<td>Generic Retailer</td>
<td>$90 (5 each)-personal contributions</td>
<td>45 each</td>
</tr>
<tr>
<td>Lithium Ion Battery</td>
<td>2</td>
<td>Amazon</td>
<td>$25 (~12 each)</td>
<td>45 each</td>
</tr>
<tr>
<td>Voltage Regulator</td>
<td>2</td>
<td>TI</td>
<td>$3 (1.5 each)</td>
<td>1</td>
</tr>
<tr>
<td>Solar Panels</td>
<td>7</td>
<td>Alta Devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Panel (backup)</td>
<td>7</td>
<td>OSEPP (Amazon)</td>
<td>$50 (7 each)</td>
<td>10 each</td>
</tr>
<tr>
<td>Light Sensor</td>
<td>1</td>
<td>Sparkfun</td>
<td>$5</td>
<td>1</td>
</tr>
<tr>
<td>Servo</td>
<td>1</td>
<td>Servocity</td>
<td>$60</td>
<td>22</td>
</tr>
<tr>
<td>3 Axis Gyroscope</td>
<td>1</td>
<td>Sparkfun</td>
<td>$10</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>ALL</strong></td>
<td><strong>ALL</strong></td>
<td><strong>$180</strong></td>
<td><strong>695</strong></td>
</tr>
</tbody>
</table>

Commented [TS36]: Check the mass of all the components some of them do not look accurate

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*It's Always Sunny in Boulder*
3.4 Team Member Profiles

**James Brannen** is an Astronomy major from Evergreen, Colorado. He has experience with AutoCAD, Revit, engineering projects, and problem solving. He aspires to do astronomy research.

**Jay Forester** is an Aerospace Engineering major from Corning, New York. He has experience with aircraft structural design and construction as well as leadership credibility. He aspires to someday help create affordable and easy human space exploration missions and help create craft to travel to other solar systems.

**Andrew Loaiza** is an Aerospace Engineering major from Colorado. He aspires to improve in his weak areas by working on that aspect of the satellite, which would mostly be research, software, electronics and his writing skills.

**Ivana Mora** is an Aerospace Engineering major from Denver, Colorado. She has experience with planetary sciences and astrophysics. She aspires to work for NASA.

**Steven Romeo** is a Mechanical Engineering major from Denver, Colorado. He has experience with the MATLAB computer language, Solidworks, construction and leadership. He aspires to make air travel faster, more efficient, cleaner and cheaper.

**Trace Valade** is an Aerospace Engineering major from Fort Collins, Colorado. He has experience with problem solving, MATLAB, and team management. He aspires to work at SpaceX.

**Taylor Washington** is an Astrophysics major from Denver, Colorado. She has experience with Solidworks, Python, and data analysis/research. She aspires to go to graduate school next semester and continue on research with her professor.

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