Colorado Space Grant Consortium

Gateway to Space
Spring 2017
Design Document

Team Greedo Shot First

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March 7, 2017
Revision A/B
Revision Log

<table>
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<th>Description</th>
<th>Date</th>
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<td>Conceptual and Preliminary Design Review</td>
<td>03/07/2017</td>
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<tr>
<td>C</td>
<td>Critical Design Review</td>
<td>04/06/2017</td>
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<tr>
<td>D</td>
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1.0 Mission Overview

1.1 Mission Statement

Team Greedo Shot First will launch a balloon satellite, (henceforth known as Project Heart of Gold, or PHOG) for the ASEN 1400 class, containing both monocrystalline and polycrystalline solar cells mounted to the satellite’s exterior in order to compare the change in efficiencies of the solar cells at various altitudes. Using the data collected from PHOG we will obtain a better understanding of which type of solar cell will be most effective for future high altitude solar power collection systems.

1.2 Overview

One of the most significant problems facing society today is to find a clean, renewable source of energy. Solar power has already proven its effectiveness in providing ample amounts of energy, yet only 1.1 percent of global energy production consists of solar power. This percentage is up nearly 30 percent from the previous year, yet there is still plenty of room for improvement (“Solar energy”, 2015). Only a fraction of solar energy that reaches Earth also reaches its surface. This is because approximately 29% of the incoming energy is reflected back to space by clouds or particulate in the atmosphere. An additional 23% is absorbed by water vapor, dust and ozone within Earth’s atmosphere (“Solar Radiation, Earth's Atmosphere, and the Greenhouse Effect,”, 2008). These numbers can vary do to different atmospheric conditions and depending on the time of year (“Earth's Energy Budget”).

Additionally, the ability to collect solar energy on the ground is vastly dependent on the weather. 80-90% of solar radiation can be lost on a foggy or rainy day (Suttida, 2013). Due to so much energy being lost within Earth’s atmosphere or due to poor weather conditions, it stands to reason that a more efficient manner of utilizing solar power is to collect the solar energy before any of it is lost in our atmosphere. Placing solar cells in a retrograde geosynchronous orbit would allow for nonstop collection of solar energy with few obstructions. Plus, there is no darkness from night in space to halt all collection of
energy like there is for terrestrial based solar cells. Research is already underway to discover a way of sending energy across vast amounts of space using microwave based or laser based transmitting devices. Once wirelessly transmitting energy is possible the use of solar energy will increase rapidly. Understanding what type of solar cell not only performs most efficiently but also performs most effectively at at higher altitudes is critical to the future implementation of solar power.

Furthermore, understanding which type of solar cell will be most efficient at higher altitudes will further our understanding of the potential of solar energy. Currently, the most commonly utilized solar cells are the monocrystalline and polycrystalline cells. Both types are composed of silicon crystals, though the main difference between the monocrystalline and polycrystalline cells is in how they are manufactured. In the monocrystalline cell molten silicon is gradually exposed to a base crystal allowing the silicon to cool slowly, thus creating a single crystalline structure. In the polycrystalline cell molten silicon is poured rapidly around the base crystal allowing minimal time for the silicon to cool in a orderly fashion, thus forming a polycrystalline structure (Tai, 2011). The slower cooling time of the monocrystalline cell allows for a higher silicon purity which directly results in generally a high solar efficiency. However, do to the vast amount of time required to make the monocrystalline cell, it cost significantly more to make than the polycrystalline cell.

When considering what type of solar cell to use for a Low Earth Orbiting power plant, it is import to consider not only the power output of the cell but also its realistic implementation. While monocrystalline cells tend to be more efficient than polycrystalline cells on Earth’s surface, they also cost substantially more. Knowing which type of cell will have the greatest increase in efficiency from ground to apogee will help determine which cell has the greatest potential of being most effective for future use.

2.0 Requirement Flow Down

The requirements for the Project Heart of Gold are shown in the tables below. Each level 0 requirement is derived from the mission statement.

2.1 Level 0 Requirements

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>PHOG shall be ready to launch by 06:50 AM on the 8th of April, 2017.</td>
<td>Mission Overview</td>
</tr>
<tr>
<td>0.2</td>
<td>PHOG shall test the current output of monocrystalline and polycrystalline solar cells for the duration of the flight</td>
<td>Mission Overview</td>
</tr>
<tr>
<td>0.3</td>
<td>PHOG shall meet all the requirements outlined in the ASEN 1400 Request for Proposal</td>
<td>Mission Overview</td>
</tr>
</tbody>
</table>
3.0 Design
3.1 Electronics Design
3.1.1. Summary
The electronics of the design will consist of four main subsystems: The heating subsystem; the generic sensor subsystem consisting of Arduino 1 and the connected sensors; the solar cell subsystem consisting of the solar panels, Arduino 2, and the connected sensors; and the visual subsystem consisting of the GoPro and its associated components. These four subsystems are shown completely in the Functional Block Diagram below.

3.1.2 FBD
3.1.3 Full list of parts by subsystem

3.1.3.1 Heating subsystem
1x 27V Heating unit
1x Power indicator LED with resistor
1x Toggle switch
3x 9V DC battery

3.1.3.2 Visual subsystem
1x GoPro Hero 4 Camera
1x 32GB SD memory card

Commented [AV13]: This section is informative but the layout isn’t great. Try to organize it in a chart or even paragraph form. Also, include supplier
3.1.3.3 General sensor subsystem

1x Arduino  
2x 9V DC battery  
1x Power indicator LED with resistor  
1x Toggle switch  
1x BalloonShield PCB unit for Arduino  
2x Temperature Sensor  
1x Barometer  
1x Hygrometer  
1x Altimeter  
1x OpenLogger data storage encoder  
1x 4GB SD memory card

3.1.3.4 Solar subsystem

1x Arduino  
2x 9V DC battery  
1x Power indicator LED with resistor  
1x Toggle switch  
1x Analog Multiplexer  
2x 5-pin analog current sensor  
2x Monocrystalline Solar Cell  
1x Polycrystalline Solar Cell  
1x OpenLogger data storage encoder  
1x 4GB SD memory card

3.1.4 Electrical Requirements Summary

All requirements for the mission are being met, as Arduino 1 is carrying the needed BalloonShield along with all the general sensors necessary for the mission. The solar subsystem involves quantitative data collection and is an experimental premise approved by Professor Koehler in compliance with the Request for Proposal.

3.2 Structural Design

3.2.1 General Structural Design

Project Heart of Gold will utilize a foam core box that has a square base of 26 cm² and is 8 cm tall. It will have a tube down the center in order to be attached to a balloon which will take it up to collect data. It will also have a layer of insulation along the inside of the box to help prevent the hardware from freezing. The interior of the box will contain a GoPro camera to take pictures during the flight, two Arduino Unos, a heater, seven 9V batteries, a multiplexer, two current sensors, and two data loggers with 4GB SD cards. The exterior of the box will have 3
switches along the sides and 3 solar panels on the top of the box, two smaller monocrystalline and one larger polycrystalline.

![Figure 1. 3D CAD renders of Heart of Gold](image)

3.2.2 Uncertainties and Limitations

The primary limitation for PHOG is the unpredictability of the flight. There is no guarantee that the monocrystalline and polycrystalline cells will receive the same amount of light throughout the flight. However, these inconsistencies should have negligible effect upon the overall trend for the two cell types, as there will be enough usable data points to reach a reasonable conclusion.

3.2.3 Concept of Operations Diagram
In summary, PHOG will meet all the requirements laid out in section 2. The design will be attached to a balloon by a flight string running through a central tube. The heater and insulation will maintain an interior temperature of above -10 degrees Celsius. There is also room on the exterior for an American flag and contact information. All equipment is expected to survive to be able to be returned to the university for future use, and the total cost and weight of the materials are all below required levels (see section 5).

4.0 Team Management

4.1 Team Overview

4.1.1 Team Manager

The main responsibility of the Team Manager is to manage the Budget and Scheduling of the team. Peter Rosenthal is the Team Manager because of his previous leadership experience. The Team Manager also is expected to help with all Structural, Software / Coding, and Science / Hardware aspects of the team.

4.1.2 Structural Team
The structural team consists of Jack Gillett, Riley Perez, and Wyatt Wear. Wyatt and Jack were responsible for the construction of the structure, while Riley and Jack are currently responsible for testing. Upon complete electronic and scientific assembly, they are responsible for integrating that into the structure of PHOG.

4.1.3 Software / Coding Team

Andrew Dellsite, and Benjamin Bruce are the two members of the Software / Coding team. They are responsible for coding the Arduinos to properly executing the scientific mission. Their code is required to run if PHOG is to complete their full electronic assembly and final testing.

4.1.4 Science / Hardware Team

The Science / Hardware team is made up of Riley Perez, Wyatt Wear, and Karim Krarti. Karim is responsible for the Science and Mission aspects, handling the solar panels and other mission specific pieces. Wyatt is responsible for the rest of the electronics, as well as the overall electronic assembly. Riley is responsible for the testing of the electronic and science components due to the close relationship between the testing of both the Structural and the Science / Hardware team.

4.1.5 Org Chart

4.1.6 Team Information

Peter Rosenthal is from Steamboat Springs, CO. He is majoring in Applied Math with emphasis in Astronomy. He is the team leader, and can be reached at pero7021@colorado.edu or 970-846-4642.

Andrew Dellsite is from Tumwater, WA. He is majoring in Aerospace Engineering. He is a member of the software team, and can be reached at Andrew.dellsite@colorado.edu or (360) 489-5574.

Riley Perez is from Bellevue, NE. He is majoring in Aerospace Engineering. He is a member of the hardware team. He can be reached at riley.perez@colorado.edu or 970-260-3971.

Wyatt Wear is from Colorado Springs, CO, double majoring in Jazz Studies and Aerospace Engineering. He is a member of the hardware team and is best reached at wywe1274@colorado.edu or 719-650-7955.

Commented [AV24]: Multiplexer??

Commented [AV25]: I know you guys tried to improve this section from the proposal, but you might have expanded too much. Combine scheduling and budget, have one testing team, construction and structural are similar.
Karim Krarti is from Longmont, CO, majoring in Aerospace Engineering. He is a member of the hardware and structure team. He can be reached at kakr609@colorado.edu or (720) 238 9792.

Benjamin Bruce is from Pleasanton, CA, majoring in Aerospace Engineering. He is a member of the software team, and can be reached at bebr4695@colorado.edu or (970) 988-6132.

Jack Gillett is from Midland, TX, majoring in Astrophysics. He is a member of the structure team, and can be reached at jack.gillett@colorado.edu or (432) 254-8022.

4.2 Schedule

Team Greedo Shot first meets a minimum of twice weekly, on Monday and Wednesday from 3-5, in the ITLL study rooms. These meetings allow for all of the work that was done individually to be compiled together and completed prior to class the next day. The Monday meetings are also important for scheduling out the rest of the week as the team breaks up into its small groups. The large-scale schedule for the entire project is as follows:

<table>
<thead>
<tr>
<th>Week</th>
<th>Objectives</th>
<th>Due</th>
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<tbody>
<tr>
<td>03/05-03/11</td>
<td>Rocket history and launch vehicles, electronic assembly, Design Document, and mid-semester evals, whip test</td>
<td>DD Rev A/B 03/07</td>
</tr>
<tr>
<td>03/12-03/18</td>
<td>Orbits and mission design, in-class team time, finalize programming and structural-electronic assembly, solar panel experimental tests</td>
<td>Evaluations 03/14 Service approvals 03/16</td>
</tr>
<tr>
<td>03/19-03/25</td>
<td>Guest lecture and in-class simulation, start launch readiness review, cold test</td>
<td></td>
</tr>
<tr>
<td>03/26-04/01</td>
<td>Spring break, LRR and RFF cards and homework</td>
<td></td>
</tr>
<tr>
<td>04/02-04/08</td>
<td>Launch Readiness Review, launch logistics, weigh-in, launch day, BIGGEST GOAL: successful launch</td>
<td>LRR Presentation 04/04 DD Rev C 04/06 RFF Cards 04/07</td>
</tr>
<tr>
<td>04/09-04/15</td>
<td>Data analysis and post-launch presentation</td>
<td>Post Launch Pres 04/13 Raw Data 04/13</td>
</tr>
<tr>
<td>04/16-04/29</td>
<td>Guest lectures and homework, final team evals</td>
<td>HW 09 04/25 Final evals 04/27</td>
</tr>
<tr>
<td>04/30-05/10</td>
<td>Reviews, team evaluation, Final and Service Presentations, homework</td>
<td>1st Draft DD Rev D 04/27 All data 05/02 Final Pres 05/02 HW 10 05/04 Final Team eval 05/04 Final DD Rev D 05/10</td>
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</table>

Commented [AV26]: You might want to expand more on launch logistics, do another mission test before break to see how everything is functioning. The final mission simulation is the most important test (in my opinion).
5.0 Weight and Monetary Budgets

The budget will be managed by the team leader, Peter Rosenthal. There is also a shared spreadsheet of the budget that will be kept updated so no team member is left unable to help.

<table>
<thead>
<tr>
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<th>Quantity</th>
<th>Price</th>
<th>Mass (total)</th>
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<td>Provided</td>
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<tr>
<td>GoPro</td>
<td>COSGC</td>
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<td>Provided</td>
<td>1.5g</td>
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<tr>
<td>Temperature Sensor</td>
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<td>Provided</td>
<td>2g</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>COSGC</td>
<td>1</td>
<td>Provided</td>
<td>1.5g</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>COSGC</td>
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<td>Provided</td>
<td>1g</td>
</tr>
<tr>
<td>Humidity Sensor</td>
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<td>Provided</td>
<td>1g</td>
</tr>
<tr>
<td>Heater</td>
<td>COSGC</td>
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<td>100g</td>
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<tr>
<td>Foam Core</td>
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<td>1g</td>
</tr>
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<td>Solar Panel T1</td>
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<td>Solar Panel T2</td>
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<td>Current sensor</td>
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<td>4g</td>
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<tr>
<td>Multiplexer</td>
<td>Sparkfun</td>
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<td>$4.95</td>
<td>3g</td>
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<tr>
<td>Batteries</td>
<td>Out-of Pocket</td>
<td>7</td>
<td>Personal</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$105.32</td>
<td>795g</td>
</tr>
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6.0 Test Plan and Results

6.1 Safety

Team Greedo Shot First understands that the equipment and materials that will be worked with, and tested, throughout this project have the potential to cause injury if not handled in the proper manner. This being said, all work will be handled with maturity and respect for equipment, whether this is during the construction or testing phase. Machinery will always be worked with in groups of at least two or three people, all of whom will be wearing safety glasses if necessary. Furthermore, tests will be handled in controlled environments, away from windows, where bystanders will be cleared of any potential danger, whether this be the drop test, whip test,
etc. Lastly, all dry ice will only be handled by team members wearing gloves and safety glasses, who will also be exercising extreme caution during the temperature test.

6.2 Test Plan

6.2.1 Structural Testing

In order to make sure that Project Heart of Gold can withstand the structural strains experienced during all stages of the flight (launch, flight, burst, and drop), three different structure tests will be conducted. The objective of these tests is to identify any weaknesses within the structure of PHOG and then make the proper modifications to ensure that it will survive the flight. During all structural tests, PHOG will be filled with mass simulators to test a weight of 850 grams, about 60 grams over the projected final weight.

6.2.1.1 Stair Test

After the descent of Project Heart of Gold, there is a very real possibility the structure could be dragged along the ground by the parachute in a very rough manner. To prepare for this, on March 1st the team conducted the stair test of the structure, after filling PHOG with a box of rocks for mass simulators rather than hardware. The structure was tossed down a flight of stairs in the ITLL building to test its durability against any tumble effects. The structure was then analyzed for damage, which was extremely minimal. Since no extensive damage was reported, no modifications were made to the structure.

Safety note: The stairway and floor beneath were monitored and cleared of bystanders to ensure safety.

6.2.1.2 Drop Test

Even with a successful parachute deployment, impact after descent can still occur at high velocities, and the team must be sure that the internal hardware will not be damaged by this. On March 1st, the drop test was conducted from the ITLL bridge after filling PHOG with mass simulators (box of rocks). The ITLL bridge is roughly 6 meters high. After being assessed for damage, no modifications to the structure were needed as the structure held together very well.

Safety note: Two team members were on the ground underneath the bridge to clear the area of pedestrians. Furthermore, the test was done during low traffic hours to further ensure safety during the testing period.

6.2.1.3 Whip Test

In order to ensure that PHOG can handle the extreme turbulence and velocities that will be experienced post-burst of the balloon, a whip test will be conducted. After being filled with the mass simulators, the structure will then be attached to flight cord and swung around for two minutes in all sorts of ways in order to simulate the previously mentioned post-burst effects. After this test is completed, PHOG will be analyzed for any damage or failures so that the proper adjustments can be made. If any flaws appear, the structure will be repaired and/or modified, then tested again to ensure no further damage.
Safety note: The whip test will be conducted in an open field, far from any bystanders, obstacles, or windows.

6.2.2 Experimental and Sensor Testing

Project Heart of Gold has many different sensors and internal hardware that must be tested before launch to ensure that all data is being recorded properly. The following sensor and experimental tests will be conducted to validate this.

6.2.2.1 Solar Panel and Current Sensor Tests

In order to make sure that the solar cells are properly communicating with the current sensors, and the sensors with the Arduino, the team will be conducting sensor tests. Team Greedo Shot First will place both types of solar cells outside for one hour while hooked up to the current sensors, multiplexer and Arduino. The team will do this in a relatively controlled environment to make sure that no outside factors inhibit the results of the test. After storing the data on the SD cards in the OpenLog, the Arduino will be tested through running the software in order to make sure everything is communicating correctly. We will then make sure the data is accessible from the SD card.

6.2.2.2 Resistor and Arduino Tests

While current will be recorded on current sensors, team Greedo Shot First will be using the Arduinos to record voltage input of the solar panels during the flight. However, the voltage output of the solar panels max out at 6 volts, and the Arduinos can only record up to 5 volts. To account for this, resistors will be used to ensure that the voltages from the solar panels are properly recorded by the Arduinos and stored on the OpenLog. Similar to the current sensor test, the team will place both types of solar cells outside for one hour while hooked up to the resistors. After this time, the data stored on the SD card will be analyzed to make sure all components of this test are working properly. If the test fails, the hardware will be re-evaluated and re-tested until the test is successful.

6.2.2.3 Camera Test

While not completely essential to the mission itself, the GoPro on board PHOG will be able to capture some amazing pictures and videos throughout the duration of the flight. To ensure that the camera will be functioning properly for the three-hour flight, the team will test both its picture, and video recording capabilities. The test will be deemed a success if both videos and pictures are properly recorded and stored for analysis on the GoPro.

6.2.2.4 Thermometer, Pressure, Humidity, and Accelerometer Tests

Team Greedo Shot First will also be flying Project Heart of Gold with a thermometer, pressure sensor, humidity sensor, and accelerometer sensor, in order to collect additional data during the flight. This data can then be compared with the data collected from the solar panels to find any correlations with solar panel efficiency. These sensors were tested in class with successful data recording on the OpenLog.

6.2.3 Mission Simulation Testing
After all other tests have been completed and PHOG is in its final stages of construction, the team will be conducting the following tests to simulate the actual mission. The purpose of these tests is to make sure that all components of PHOG are able to work together properly for the full three hours of the flight.

6.2.3.1 Temperature Test

While Project Heart of Gold makes its ascent to 30,500 meters, it will be exposed to extreme temperature drops, as low as negative 60 degrees Celsius. These drops in temperature could very well impair the internal hardware and the solar cells themselves. In order to test this, the structure (filled with its hardware) will be placed in a cooler full of dry ice for one hour, running as it would during the actual flight. The team will then make sure that the structure is insulated well enough for the hardware, and that the heater is working properly. Once again, the necessary modifications will be made to the structure to make sure that temperature does not compromise the integrity of the mission. This test will be handled with extreme caution as previously stated, and only by team members wearing the appropriate equipment (gloves, hoodies, etc.)

6.2.3.2 Mock Mission Test

The final test to be conducted will be the mock mission test. Project Heart of Gold will be placed outside for three hours with the camera, solar panels, and sensors on and functioning. After this time, all data will be analyzed to make sure that all hardware components are properly communicating with each other, and that the data is stored and makes sense. If any failure or corruption of data occurs, PHOG will be re-analyzed to locate the source of failure, modified, and then retested until the mock mission test is a success.

6.3 Test Results

6.3.1 Structural Testing

6.3.1.1 Drop Test Results

The drop test showed that the PHOG structure is durable enough to withstand large amounts of shock even when dropped with a higher weight than necessary. No extensive damage was recorded, so no structural modifications were required.

6.3.1.2 Stair Test Results

The stair test showed that the PHOG structure can withstand any tumbling or dragging it may experience post-landing from the parachute. No extensive damage was recorded, so no structural modifications were required.

6.3.2 Experimental and Sensor Testing

6.3.2.1 Thermometer, Pressure Sensor, Humidity Sensor and Accelerometer Test Results

All of the above sensors were tested in class with the BalloonShield and Arduino. All sensors were functioning properly, with data successfully stored on the OpenLog SD card.

7.0 Expected Results

7.1 Solar Panels
7.1.1 Data from the Scientific Community

PHOG will gather data on photovoltaic output throughout the flight. Both current and voltage data will be tracked for both types of solar panels. The atmosphere absorbs and scatters some of the light from the sun, so it is the expectation that there will be some increase in power output over time. Researchers at The American Society of Mechanical Engineers ran a similar experiment in 2011, and found an expected increase in power output with a rise in altitude.

Note that the above data has been normalized for area and angle of incidence. Both factors must be considered when running the solar panel experiment, because PHOG will ascend over the course of a few hours, and the sun will be rising in the sky over that time. Throughout the flight, sunlight will be striking the photovoltaics at a more direct angle, increasing power output independent of altitude. This change in angle of incidence is by far the strongest factor in determining power output. Furthermore, the two types of solar panels have slightly different total areas, which will impact the raw output as well. Another extraneous factor is the temperature of the solar panels, which is known to change the power output of most photovoltaic solutions. For mono and polycrystalline solar panels, colder temperatures are conducive to power production.

7.1.2 Expected Data from PHOG

The raw data output from the sensors onboard PHOG will not be as clear as the above plot. As previously stated, we will need to adjust for known skew factors before arriving at useful data. That being stated, we expect the raw output from the current sensors will likely show a clear positive trend over time, with a change in curvature at the moment of balloon collapse, as trends in temperature and altitude reverse. There will likely be several irregularities in the data as a result of tumbling and rotation of PHOG. We are hoping to see some notable difference.

Commented [AV44]: You need citations for all graphs in this section. Even if you did have a source for the graph, it's not organized.

Commented [AV45]: You need a plan on how to account for this, how much will this affect the trend?

Commented [AV46]: All graphs need phases of flight labeled to show any rapid changes during flight.
between monocrystalline and polycrystalline solar cells as well. It is known that the former are slightly more efficient at ground level, though there is very little data on how altitude affects different types of solar cells, so we cannot make any strong claims for what will happen on PHOG. Below is a tentative plot of expected solar panel current output with respect to time. Note that descent begins at approximately 130 minutes.

7.2 Sensor Suite

7.2.1 Humidity

We expect humidity to generally drop as altitude increases, due to lower temperatures causing water vapor to condense and fall. Depending on weather conditions during launch, there may be a spike in humidity as the balloon rises through cloud layers and emerges into the stratosphere. At this point, most of the water in the air has frozen, so we expect humidity to remain very low throughout most of the flight. The reverse will occur during descent, except within a smaller timeframe.

7.2.2 Temperature

We expect the temperature sensor to read a drop as the altitude of the balloon increases, until it passes the ozone layer, where the temperature will begin increasing. Initially, the plummeting pressure and humidity of the air will reduce its ability to hold heat, resulting in a

Commented [AV47]: These graphs should be larger.
Commented [AV48]: Mention phases of flight/label on the graphs.
Commented [AV49]: These trends look pretty close around 130 minutes (burst), so I would look into how the extraneous factors are going to affect the trend (as stated in a previous comment).
downward trend in temperature. The shift occurs because at the apex of the flight the atmosphere is thin enough that solar radiation will strike the balloonsat at nearly full intensity, with very little scattering or absorption from the air. The reverse will occur during descent, within a smaller timeframe.

7.2.3 Pressure

We expect the air pressure to drop rapidly with altitude as the balloon rises, in a pattern somewhat similar to exponential decay. This distribution can be interpreted as a result of the gravitational force from Earth, which attracts more strongly closer to the surface and will therefore result in more air particles, and therefore greater air pressure, near the surface.

7.2.4 Accelerometer

It is difficult to predict with very much certainty what the acceleration data will look like, though it seems likely that launch, balloon collapse and landfall will represent the greatest spikes.
in the z direction. There will be other, less predictable spikes in the data as a result of normal jostles and rolls of PHOG.

Citations


Commented [AV52]: Citations must be footnotes. Instead of creating a blob at the end, format these correctly with proper notation and in the footer of the page you reference it.


