Team Zeus Presents

Performance of Flexible Amorphous Photovoltaic Solar Cell in the Near Space Environment

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Abstract
Solar cells have become increasingly cheap as technology has increased. This has allowed for smaller, more efficient, flexible solar cells than the previous generations. This generation of solar cells has the ability to conform to any shape while at the same time being efficient. Unfortunately not much testing has been done regarding amorphous photovoltaic solar cells. Our team will be measuring the potential and performance of these solar cells in the near space environment. The data our team will collect could potentially show the viability of an aeronautical aerospace vehicles being completely powered by solar power technologies. These vehicles, if viable, would be cheaper to launch than conventional satellites and would be able to be operating for months, even years at a time. Such vehicles could be used for cell phone transmission, environmental analysis, surveillance, and even other experiments.

We plan on using two flexible amorphous photovoltaic 7.2 volts solar cells. These will be conformed to a cylinder shape in order to give uniform data regardless of the angle to the sun. Our solar panel systems will be measured individually along with external temperature, pressure, and humidity readings to be compared against our solar panel power output. Throughout the entire flight we will have a ground solar cell to compare against our in-flight solar panels, this will be our control. If successful, we will find optimum locations in the atmosphere for flexible amorphous photovoltaic solar cells to operate at maximum potential allowing for optimized solar flights for aeronautical aerospace vehicles.

1. Introduction

1.1 Preface

With a constant rise in the consumption of non-renewable energy, Team Zeus has decided to experiment with flexible solar panels in the near space environment. Our goal is to determine the feasibility of using solar cells as an alternative solution to power future aeronautical aerospace vehicles. Such vehicles could revolutionize the aerospace industry by creating cheaper, more efficient means of cell phone communication, weather observations, global imaging, and/or GPS. These vehicles could potentially be much cheaper than launching conventional satellites. Such ideas are currently being explored by many different companies, one of them being Facebook. They are currently planning on creating solar powered drones that would one day provide internet to regions that are currently not connected (BBC). Google is working on a similar project that would be in direct competition with Facebook. The data we will collect from our payload will help pave the way to a better understanding of solar technologies in the near space environment.
In our experiment, we are going to mount two flexible amorphous silicon solar cells onto the sides of a cylindrical payload. The payload is a cylindrical shape with flexible solar cells that wrap around the circumference. This design will enable us to have constant voltage readings throughout the flight. The cylinder shape will also allow the voltages to not be affected by rotation of the payload during flight. An advantage of using these types of solar cells is that they work extremely well in low light environments. Another advantage of these types of solar cells is that they produce a constant voltage throughout a wide angular range.

The payload will also be equipped with a pressure sensor, temperature sensor, and humidity sensor. Data will be collected from each solar cell, and will be compared against altitude readings, temperature readings, and humidity readings. These sensors will help us determine if temperature, pressure, and humidity will affect our power output. To help create more viable data, we will have a control payload on the ground. Our control payload will have an additional flexible amorphous silicon solar cell with a temperature sensor as well. When our payload is launched into the atmosphere, we will simultaneously be collecting voltage and temperature readings from the ground. This will be compared against our data from the upper atmosphere.

1.2 Science of a Solar Cell

Photovoltaic cells are composed of a semiconductor material like silicon. Silicon is a perfect material for a semiconductor because its outer shell is only half full. One plate of silicon is then doped with phosphorus to create n-type silicon which acts closer to a conductor with free electrons. Another plate of silicon is doped with boron which creates p-type silicon which has “holes” desiring electrons. When the p-type and n-type silicon is in proximity it creates an electric field (Perlin). The electric field reaches equilibrium and only lets electrons flow from the p-type to the n-type but not the other way around. When a photon from the sun hits the solar cell it knocks an electron-hole pair free. By providing a path for the electron, work can be extrapolated from the solar cell, thus creating power (Perlin).

2. Mission

2.1 Mission Objectives

In our mission to the upper atmosphere we have several mission objectives. One objective is to collect voltage readings from two 7.2V flexible amorphous silicon photovoltaic solar cells to determine power outputs at different altitudes. Another objective is to collect temperature, pressure, and humidity readings at different altitudes to be compared against the power output readings. Our final objective is to determine the optimal altitude for flexible amorphous silicon photovoltaic solar cells to operate at.

2.2 Mission Expectations

In this experiment, Team Zeus is expecting the following observations. First we expect that the solar cells power output will increase linearly as the temperature decreases due to a decrease in internal resistance. We expect that the solar cells power output will increase linearly as humidity decreases due to less molecules scattering photons. We expect that the solar cells power output will increase linearly as altitude increases because solar radiation in the visible spectrum with increase with higher altitudes with less particles absorbing those photons. Last but not the least; we will discover that there are locations in the atmosphere that solar cells will have optimum performance.

2.3 Special Requirements
Our payload will be a cylinder shape in order to insure that the energy collected from the sun is as uniform as possible. With a cylinder, the payload should be able to have a controlled energy output through our solar panels. The payload will be utilizing flexible amorphous silicon photovoltaic solar cells. It will generate up to 1 watt of power. The cells should give us uniform energy output no matter what angle the sun is. This will allow for a more controlled experiment.

3. System Construction

3.1. Cylindrical Box Design

The cylindrical box is made up of Mat paper and Styrofoam. We cut a piece of mat paper with the dimensions of 19cm by 64 cm using a pair of scissors. This will serve as the body of the payload. Next, we will use two precut Styrofoam cylinders with a radius of 20.3 cm to serve as the main structure. We will then attach the bottom of the mat paper using hot glue and aluminum tape. For the insulation we will wrap foam around the inner sides of the cylinder and attach with hot glue. We will then reinforce the box with electrical tape and glue so that it will be firm enough to withstand all of the harsh conditions during the flight. Two solar cells will be mounted outside on the side of the box. The solar cells will be attached to the cylinder by using hot glue.

3.2. Internal Design

We will program the Arduino to read voltage off a load connected to each solar panel. The two solar cells will be connected independently to the Arduino. Three resistors each will be connected in a series circuit to each solar cell. Since the Arduino has a maximum capacity of 5 volts, these resistors will help step down the volt so that it does not blow up the Arduino. We will then calculate the total power generated by the solar cell using ohms law. Next, we will integrate the temperature, humidity, and pressure sensors with the Arduino. To keep the components warm we will have a heating circuit and connect it to two 9v batteries. The resistors will also help to heat up the box and keep the internal temperature above 0°C. We will have four switches attached to the top lead of the box. Two of the switches will be for the solar cells, one for the Arduino and one for the heater circuit. The final component is the camera. We will make a small circle towards the bottom of the cylinder. We will then program the camera to take pictures every 30 seconds. The temperature sensors will be towards the outside of the cylinder, this will allow us to see the conditions of each solar cell. All of the data and pictures will be collected by the Arduino and stored in the SD memory card.

3.3. Computer Aided Design

Overview Model

To Scale Model of Payload

Exploded View
3.4 Payload Photographs

Overview Model

Inside of Payload Side View 1

3.5 Electrical Schematics

Solar Panel Circuit

Heater circuit
4. Subsystem

4.1. Requirements

The temperature sensor shall produce a voltage based on the outside temperature. The voltage will range from 0 to 5 volts. The pressure sensor shall give the pressure outside the structure at any time during flight. The sensor will have a voltage based off of pressure, and it will range from 0 to 5 volts. The humidity sensor will create a voltage based on the outside humidity during flight; the voltage of the sensor will range from 0 to 5 volts. Two 9 volt batteries shall supply the heater circuit. This will then keep the internal temperature above 0 degrees Celsius. The batteries will supply the heater circuit with a constant flow of current and constant voltage. One 9 volt battery shall supply the Arduino Uno with a constant current and voltage throughout the entire flight. The Arduino will receive analog signals, change them into digital signals, and record the signals on an SD card. The Arduino will change the analog signals into digital readings with increments of .01 units. The panels will stay mounted to the structure and produce a constant voltage and current based off the amount of sunlight. The solar panels will produce an analog signal that is then transmitted to the Arduino. The voltage will range from 0 to 10 volts. It will then be brought down 5 volts or below by using two 50 ohm resistors and one 25 ohm resistor. The Arduino will record it onto an SD card. The increments that it will record all of the digital signals will be 0.01 units. The Arduino will have read the voltage off each solar panel at a certain point, the analog signal will then be converted to digital and sent to the SD card and saved. The voltage will be saved in increments of .01 units.

4.2. Testing

1. **The Drop Test** - The payload will have to withstand hard impacts with the ground. This test will simulate possible
landing impacts. We will drop our payload with simulated weights from a height of 20 ft. We will continue dropping our payload for up to five times.

**Results:** After dropping from 20 ft several times, the box had minimal damage. The bottom lip of the box was folded. They were some slight wrinkles towards the center of the box. The box was still fully intact.

2. **The Whip Test** - The payload must be able to withstand all rotational forces such as rotational acceleration. This will be simulating rotational forces on the payload. We will swing our payload with simulated weights in a circular motion above our heads with an attached cable. We will swing the payload for up to three minutes.

**Results:** The test lasted for 3 minutes. The payload was whipped around and even hit the ground at one point. The box was barely damaged. The bottom lip previously folded in the drop test came off the payload slightly.

3. **The Kick Test** - The payload must be able to withstand all the G-Forces that are produced during the trip. This will simulate extreme external G-Forces. We will kick our payload with simulated weights down a flight of 8 stairs. We will repeat this test a total of five times.

**Results:** The box was kicked down a flight of stairs several times. The box was not damaged. The only difference between before and after the test was some mud on the side of it.

4. **The Freeze Test** - The payload and components must be able to survive the extreme cold temperatures of the upper atmosphere. This test will simulate those temperatures. We will take our payload with all components and stick it in a cooler filled with dry ice. The heater will be on as well as all the sensors. The cooler will then be sealed off for one and a half hours.

**Results:** The payload was taken out of the box after the cold test and then taken outdoors and then it was shut off. The data log results displayed a decrease in temperature. The lowest temperature logged was 10.4 degrees Celsius and this was right outside the box. It is safe to assume that inside the box it was much warmer. The box did not suffer any failure.

5. **The Camera Test** - We will turn on the camera with preloaded code for up to one hour. We will then view the SD card and determine if the code worked properly.

**Results:** The camera was able to take pictures for up to 5 hours on a full set of AAA batteries. This exceeded our expectations for what we believed the camera would be able to do.

**The Solar Exposure Test** - We will expose our solar panels to one hour of sun light every day while connected to the voltage sensor. We will then analyze the data and extrapolate test results.

**Results:** After an hour of sun light every day our voltage averaged to around 10.3 volts for an open circuit. After verifying that voltage was being produced, we attached it to a load to then be read off our Arduino. Our solar panel achieves around 5 volts with 0% cloud cover. With 100% cloud cover our solar panels average around 0.8 volts.

**The Control Test** - We will be testing our ground control payload on the ground in multiple conditions outdoors. These conditions will range across possible spectrums to insure the ground data collected is viable. Once the data is collected it will be compared to the launch data. This will take place over multiple days.
**Results:** After multiple tests our ground control payload works as expected. We will continue to collect data now until launch on 4/12/14 to be compared against launch data. This ground payload will also be collecting data as our solar panel is in the upper atmosphere.

5. **References**

<http://books.google.com/books?id=xHFK9cM77a8C&pg=PA50


6. **Conclusion**

Solar Cells have the potential to revolutionize the aerospace industry. Flexible amorphous silicon solar cells in particular, could allow for more versatile aeronautical vehicles. These cells are beneficial because they can be placed without restrictions due to their flexible nature. By finding the optimum altitude for these solar cells to operate at, solar power could be maximized increasing the viability of solar powered flights. Such solar powered flights could be used in a variety of applications that could enhance or even replace existing satellite technologies. Furthermore, through examination of these flexible solar cells at high altitudes, our experiment will help progress the field of solar technology.