Application of Solar Cells in Ballooning to Reduce Weight in Louisiana Space Consortium’s La-ACES Program.

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Abstract

In order to minimize weight while ensuring the integrity of the mission, the use of solar cells to power the Louisiana Space Consortium’s Louisiana Aerospace Catalyst Experience for Students (La-ACES) Missions was explored in this project. These missions provide La-ACES student teams the opportunity to perform science related experiments in earth’s atmosphere. The components of each baseline payload design include an energy source that may limit the amount of science a student team may be able to perform, and that is quite heavy. The implementation of solar power as the primary energy source was introduced as a way of minimizing this constraint. It therefore allows the student teams in the space consortium to eliminate the use of archaic battery power from each payload baseline design and implement solar power. While this compensated for low weight, and budget, additional scientific measurements were equally made during flight. The Southern University and A&M College (S.U.) La-ACES Team tested solar cells for efficiency and practicality. The mission concept was to fly two types of solar cells on a latex sounding balloon at an altitude of 100,000 feet. The superior solar cell would be used in the modification of the La-ACES baseline payload design. Voltage and current readings were used to infer superior performance of each cell. Initial tests found Solar Cell B to be the most efficient solar cell for the Louisiana Space Consortium’s La-ACES Missions.

Introduction

As the number of institutions in the Louisiana Space Consortium’s Louisiana Aerospace Catalyst Experience for Students (La-ACES) grows, the scientific research and discoveries performed by each institution can also greatly increase. The utilization of solar cells for each La-ACES mission can offset weight constraints using solar power instead of conventional battery power. This technology would allow room for additional measurements and observations during flight, as investigated by the Southern University Louisiana Aerospace Catalyst Experience for Students (S.U. La-ACES) team. In order to implement this type of modification to each baseline payload design, the S.U. La-ACES team proposed testing two types of solar cells during flight with two objectives in mind. The first objective was to measure the light energy conversion of the solar cells as a function of altitude. The second objective was to find the best suited solar cell able to power future La-ACES projects by comparing the power output and efficiencies of each solar cell as a function of altitude.

Flight Operations

“A BalloonSat is a small student-built device, designed to investigate some aerospace related topic” [1]. When flown, the flight vehicle consists of three to four student BalloonSat payloads, a 2000 gram latex sounding balloon, a 60-inch parachute, a radar reflector, GPS receivers, and antennas. To be eligible for flight, each institution’s BalloonSat payload must weigh less than 500 grams. Therefore, size constraint...
is an important factor to consider when designing and building each BalloonSat payload, since size and weight are linear variables. Each flight will last 2.5 to 3 hours from launch to landing. Flight operations take place at the National Scientific Balloon facility, operated by the National Aeronautical Space Administration, in Palastine, TX.

**BalloonSat Payload Design**

The Southern University La-ACES measured the efficiency of two types of solar cells as a function of altitude. In order to make these measurements, the payload comprised two modules. The inner compartment, which served as a capsule for the electronics is the first module. Its main purpose was to provide additional safety for the electronics, such as the BasicStamp Chip, multi-plexor, real time clock, etc. The outer module was installed to shield the measurement devices from outside extremes. Also on this outer module were attached two pairs of 45 degree wings in order to improve each solar cell’s orientation to the sun. Each wing contained a solar cell “packet,” which consisted of nylon stand-offs, a Balsa wood frame, wire mesh, and the solar cells. Adequate provision was made to provide for the exhaust of heat generated by the solar cells. Such waste heat could be detrimental to the foam core each module was made of.

![Figure 1: Solar Cell Packets](image1.png)

![Figure 2: Payload Assembly](image2.png)

**Payload System Operations**

As the sun shines and photons come in contact with solar cells, electron-hole pairs are freed. Work, known as current is done as these electrons are freed and positioned back into a hole. Once current is generated, the analog-to-digital converter (ADC) receives the signal. It then deciphers the correct solar cell channel to use, and converts the signal from analog to digital. This digital signal is then processed
through the Basic Stamp and sent to memory for storage; while the real time clock “tracks” all data processed through the Basic Stamp. The temperature readings were also taken by the ADC using the same technique.

**Testing**

The S.U. La-ACES BalloonSat payload endured rigorous testing for 1.5 weeks. Shock and vibrations tests were performed on both the modules, and electronics. Attention was paid to the solar cells and the batteries during the tests.

**Solar Cells**

Two types of monocrystalline solar cells A, and B purchased from two different manufacturers were tested in open sun light. Solar cell A produced an open circuit voltage of 0.55V, and a short circuit current of 160mA, while solar cell B produced an open circuit of voltage of 0.55V, and a short circuit current of 2.5 A. Figures 3, and 4 below show the graphs of current and power versus voltage for solar cells A and B.

![Solar Cell A](image1.png)

Figure 3: Solar Cell A Current and Power vs. Voltage

![Solar Cell B Current vs. Voltage](image2.png)

Figure 4: Solar Cell B Current vs. Voltage

![Solar Cell B Power vs. voltage](image3.png)

Figure 5: Solar Cell B Power vs. voltage

**Lithium Batteries**

Lithium batteries were tested for over an eight-hour period to provide data for comparison. In order to simulate the atmospheric temperatures at 100,000 ft above the earth surface the modules would
encounter, CO$_2$ was used in the insulated compartment. The batteries were then exposed to this environment, and voltage readings recorded at temperature ranges of 25 to -70 degrees Celsius (-95°F to 80°F). In figure 6 below, once testing began voltage readings remained constant for about an hour, and thereafter declined in a parabolic manner for 3.5 hours, from 2.5 volts to 2.1 volts. This 0.4 voltage change would predictably take place during the ascent of the flight vehicle - the first two hours of flight; and thus would result in a significant decrease in power.

![Figure 6: Battery voltage degradation over Time](image)

**Results**

The battery voltage was adversely affected by the extreme temperatures, and environment. The solar cells therefore would be the best choice for the launching of the modules in space. This degradation in voltage would be a likely impediment to the success of the experiment and project. The trend in the graphs of the solar cells seems to show a gradual decrease in current and power as voltage increases, though the current and power start to decrease at a much faster rate than voltage after 0.4 volts. Although this is anticipated, solar cell B still performed much better in this respect than solar cell A, and additionally responded to the environment better.

**Conclusion**

The Southern University La-ACES team will prove the above concept by executing a second attempt of the payload system operations as described earlier on. In flight operations each payload is scheduled to ascend to 100,000 ft into space. At this altitude temperatures could reach -40 to -50 degrees Celsius. Test results show that such extreme temperatures would negatively affect battery voltage output. Such effects degrade power output and could hinder or damage payload electronics. In addition, using solar cells would also supplement for weight constraints, since 6 solar cells account for only 10% of the weight of 6 batteries. For these reasons it is believed that the use of solar cells as described in this paper, best fits the purposes of the scientific payload as well as other institutional projects in the Louisiana Space Consortium.

**References**


