Solar Balloon Satellite

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Abstract
As technology has improved, the amount of commercially available solar panels in the market have increased steadily throughout the years. Our primary mission as the Sirènes Du Soleil was to test the efficiency of commercially available solar panels at low temperatures. Our secondary mission was to create a environmentally “green” balloon satellite (Sat) by not only powering it fully on solar power, but also by reducing our waste and usage of single application materials and creating a reduce/reuse/recycle plan for all our materials. A previous Trinidad State team was awarded the “green” Sat award, as such we already have a majority of the materials available to continue that vision. This led us to our tertiary mission of creating our Sat by not exceeding 50% of last year’s budget of $800 dollars. The testing and results we have yielded so far have suggested that we are not only correct in our hypothesis that the panels are more efficient at lower temperatures, but also we have observed that the Arduino Uno is able to operate and function at a much colder temperature than originally thought, thus creating our quaternary mission; testing the Arduino Unit with minimal insulation and heat in order to find its temperature baseline. We believe based on the data we have gathered, heating units and additional insulation are strongly dependent on individual Sat payload experiments, and not necessary for the continuous running of the unit.

1. Introduction
When our team met for the first time we agreed that we wanted an environmentally “green” balloon satellite (henceforth called Sat) and that we wanted it to be solar powered. As we began researching the best panels, where to get them, and how much would they cost, we came across numerous articles that discussed solar panels and their increased effectiveness at lower temperatures[1]. This seemed like fantastic news seeing as we know that our Sat would have the possibility of entering temperatures around -80 degrees Celsius. After finding articles from NASA[2] about the types of panels they use on their various missions we decided ideally we would like to find a silicon based polycrystalline panel that was both commercially available and cost effective.

Figure 1. Solar Panel Tri-Cell Diagram

Our polycrystalline tri-cell solar panels have three colored cells to maximum wavelength capture. This image is from the manufacturer Jiang.

After finding panels to suit our specifications we began looking into the different ways we could maintain our efforts of creating a “green” Sat. We started by using materials we had from previous years to as well as researching other ways to limit our impact on the environment. We also looked at the last Sat’s budget and set our full budget to $800 with the hopes of not exceeding $400 to keep our Sat more cost effective as well.

Throughout the development of the project we discussed various other science experiments, like CO2 sensors, or video footage. However after much deliberation we decided to focus solely on our Sat being able to be powered only by the sun and how to measure the effectiveness of the panels as the temperature around them decreased.
2. Design

Our original designs were over complicated and oversized. We settled on a simple two-box design. We have the interior box measuring slightly larger than the Arduino unit plus wire and circuit board. Our exterior box is nearly three times larger. The empty space between the boxes is filled by insulation, while the interior shell is affixed to the flight tube and suspended in the middle of it all. After trying the solar panels at different angles we discovered that they received the same energy readings angled 60 degrees or completely vertical, so for our final design we decided to use hot glue and aluminum tape to stick the panels to the outside of the box.

The smaller box is the interior box to hold the Arduino Uno unit (pictured on top of the box). The larger box is the exterior shell of the Sat with solar panels already attached.

Figure 2. Solar Satellite Shells

3. Materials

We reused the recycled foam board, and starch based packing peanuts that the previous team purchased. Allowing us to not use any of our budget or buy more single use materials. We also dismantled heaters, circuitry, and flight tubes from the Sats that came before us. We also had our zener diodes and dry ice donated.

In the end we only purchased the solar panels and some aluminum tape keeping us well under our budget.

3.1. Recycled Materials Plan

It was our vision to have a plan for all materials used, whether they are recycled or repurposed. We also minimized our waste by using chalk boards and taking photos of them instead of numerous sketches on paper. When we did end up using paper we used the backs of old assignments and papers gathered from various departments on campus. All storage of photos, data and research have been maintained in a shared google drive to minimize waste even more.

3.2. Recycled Foam board

The foam board was purchased by last year's team and had 20 panels when we started. Using the leftovers makes sense for our “green” vision and for staying under budget, as the box of panels originally cost the previous team over $200 for 25 boards. After making a few different models we are down to 14 boards remaining. These will be utilized by future programs and classes here at the college. The models we created that didn’t work out were either dismantled and used for parts for our current model or have been repurposed as storage containers or art projects.

3.3. Heaters and Circuitry

When planning out our needs originally we cannibalized the heaters and circuitry from previous Sats and created ones to fit our own purpose, using only materials we already had access to here in the science building. We did end up with a donation of zener diodes to protect our Sat from oversaturation once our testing confirmed it could be an issue. We ended up not needing the heaters and returned their materials to the closet. We planned on using the residual heat that is produced by the electronics to heat the interior shell.

The wiring for our custom circuit board. All parts seen here were either donated or cannibalized from other projects no longer in use.

Figure 3. Custom Circuit Board

3.4. Insulation

The insulation we chose to use was part of the remaining bag of Soy based insulating peanuts that was used by the previous team. They are water soluble, non-toxic, and edible. Instead of using a possibly toxic adhesive or having to use our budget for the purchase of an expensive eco-friendly adhesive we just filled the
entire cavity around the interior shell with peanuts for insulation.

We also wrapped the inside of the interior shell in aluminum tape to help with heat loss from the inside out. Working with our advisor we were able to use a special code to help us know how much insulation and power would be needed to keep the interior box at a certain temperature.

3.5. Solar Panels

The panels we purchased off of Amazon.com were around $13 a piece. They each are advertised to produce 6 Volts in direct sunlight. They received top reviews from purchasers and were rated well for their produced voltage in less ideal lighting conditions. We decided to purchase 8 panels in total. Our original plan was to use four panels for the Arduino and data and four panels for the heaters. After testing we decided to use all 8 for the Arduino and testing alone.

Our panels are tri-cell photovoltaic silicon based polycrystalline based panels. They are flexible and waterproof. They are similar to the ones we researched, were purchased from Amazon, and within our low spending budget.

3.6. Arduino Uno

We used the Arduino Uno unit that was provided free in a training kit provided by COSGC to our school’s STEM department. Outside of the training code which we edited to suit our purposes, any other coding was created by our team.
the energy to avoid oversaturation. The energy leaving the diodes also gives off heat, which would have detracted from the amount of insulation needed.

We performed numerous other tests on our Sat and individual components. The drop, whip, and stair tests proved our shell design could withstand the journey physically.

The most exciting test for us was the dry ice test. We did this test twice. On the first round our wires were connected by clamps. Due to the extreme cold of -76 degrees Celsius one of our clamps failed and we lost power around the 80 minute mark. Due to us also failing to wire an led light we were unaware we lost power during the cold test. After assessing our data gathered we realized the Arduino recorded temperature as low as -68 degrees Celsius before shutting off. Armed with this information we were curious if the Arduino would survive a full 3 hours at the low temperatures we recorded. After research we found contradicting information, and we decided to test it ourselves.

During our functional testing stage we tested each panel individually in both full and partial sunlight. We wanted to get a baseline and to check for any differences between each panel's produced voltage. All the panels read between 5.9-6.4 Volts in direct sunlight and 1.1-3.6 in partial sunlight. The advertised value of 6 Volts is well achieved. However, if the panels dropped below 50% sunlight the voltage drastically decreased. Knowing this information we then set out to test the best way to wire the panels. We tried both in series and in parallel working our way up from two panels to all eight before we achieved the necessary output even in indirect sunlight. Our Arduino unit stops recording data at 4.8 volts in. Wiring panels on opposite corners in parallel, then all of them in series we are able to keep the unit running even under the worst lighting conditions. With our wiring we were able to achieve 12.5-13.6 Volts in direct sunlight and a minimum of 6.0 when panels were shaded on 50% of the box.

We built our own circuit board to include a way to wire the panels through resistors prior to the energy entering the Arduino. Doing so gave us a way to measure and track how much energy was being pulled in from the panels. Based on our functional testing we knew we had to account for the surge in power going from minimal light to maximum light. Our solution was the incorporation of zener diodes that would help dissipate

4. Testing

The secondary cold test was done indoors using an alternate power source. We hypothesized that the unit would continue pulling energy at the coldest temperature for the full test. We simulated the average level of power we could receive from our panels.

For the second test we kept the same design and insulation levels, but instead of focusing on keeping it warm, we focused our attention on the data collection and temperature sensors. The second test was completed successfully. After analyzing the second round of results we discovered we were correct in our assumption. The Arduino and components not only survived at the lowest temperature of -76 degrees Celsius, but it recorded accurate data the entire time.

We tested our insulation in tandem with our first ice test. We assembled the Soy peanuts into a box and placed them on a device used to measure heat conductivity. We were unable to find the technical specifications for our particular brand, but we estimated that the Soy peanuts were about the same heat conductivity as cork. The device used steam to melt a block of ice that was placed on top
of a box full of our chosen insulation. We then collected and measured the amount of water lost over a minute and used an equation to determine how effective the insulation was.

**Figure 10. Insulation Conductivity Test**

By placing snow from outside on top of a box filled with our insulation materials we calculated the conductivity of our soy peanuts.

After testing we learned we were accurate and that in order to keep the unit above freezing we needed to increase the amount of insulation we were using or add heaters. Our results from our secondary ice test coupled with the need for extra insulation, gave us the idea to attempt the launch with a fully solar powered Sat, that is not heated by heaters, and has the bare minimum of insulation.

### 4.1. Budgets

Financially we achieved our goal of staying under budget at only $116 out of our self reduced $400 (initially $800). In order to be ready for launch no additional materials are required at this time.

Time wise we were right on schedule with the finalizing of the control panel and attaching of the eco-friendly paper stickers that were being made by a team member.

The overall weight of our Sat was only 679g out of the allotted 800g.

**Figure 11. Weight Budget**

This is the breakdown of weights for each of our components.

### 4.2. Proposed Results

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We speculate that given our findings that our Sat would have been capable of being powered solely by the solar panels we chose. We also believe that a heater would be proven to be an optional component and would mostly be dependent on the science portion of the payload. Since our main focus of panel efficiency is unaffected whether the internal unit is kept at or above freezing, there was no need for us to incorporate one. We also believe that the panels would have functioned about the same, with minimal improvement once in colder temperatures. The day we performed our initial testing of the panels and their voltage it was 27 degrees Fahrenheit outside. It’s likely from the data we gathered it would function about the same. The only difference would have been the impact of direct sunlight without much, if any, atmospheric disruption.

### 5. Future of our Sat

Our Sat has entered into hibernation at about 90% completed. Having passed all tests our final adjustments were minimal and included the final sealing of the box and the completion of the exterior control panel. The adhesion of the identifying stickers will also need to be completed.

### 6. Conclusion

Once our Sat is able to launch and bring back data we have many questions we are hoping it will answer. Although we have seen many failures and redesigns with this Sat, we are very grateful for all we have learned. As a group of non-science majors we have strived to achieve the level of excellence and high expectations that the COSGC has placed on us. In our eyes at this stage we are happy with our Sat and the progress we have made. We will be waiting for a new launch day with anticipation and pride. We hope our potential findings of the Arduino’s ability to withstand the colder temperatures and the ability to fully operate a Sat using only solar power will encourage other teams to test their theories and create even more eco friendly “green” Satellites in the future.

### 7. References
