Design Notebook

Deployable Solar Panels for CubeSats

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Mentor: Dr. Ramana Pidaparti, Parker Ensing

Introduction/Summary

In the senior capstone, I mainly contributed to most of the software work and the presentation. I also worked as a member of the electrical team. I tested the portable battery simulation with Cole. I created an entire diagram system flowchart using the software, called Drawio. I designed the circuit on Multisim and tested it on a breadboard. I also created the foundation for the poster. I attended group meetings to discuss problems and or design decisions we wanted to implement. I also checked the milestone due dates and reminded my teammates. During the fabrication, I helped the mechanical team with the final prototype. In addition, I contributed to the ELC and Edusource milestones completed by the group. Sometimes, when our team lead forgot to submit the reports and videos, I supported him to not miss any submissions.

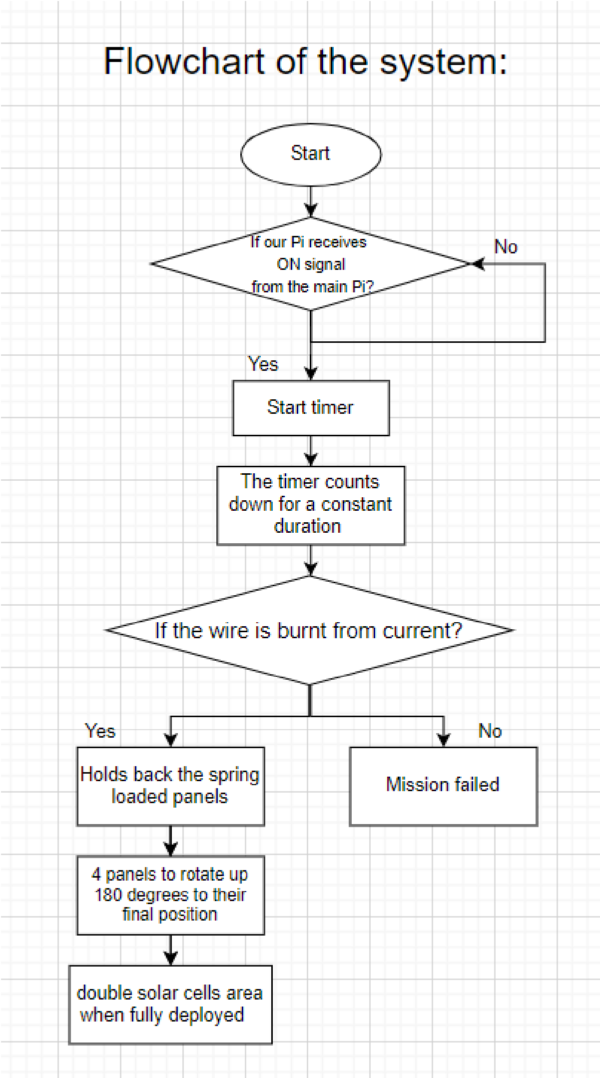
Ideas/Discussion

My mission was to create a deployable solar array for one of their 1U Cube Satellites. Because of the 1U Cube Satellite's small size, power generation is a common problem, which results in limited capabilities for the satellite. To fix this problem, deployable solar panels are often used. The solar array is stowed away during launch and deploys once the satellite is in space. The solar array will provide the satellite with enough power to fulfill its mission. We successfully designed a deployment mechanism that maneuvers open four solar panels to increase the surface area of the satellite for solar cells to be attached to.

Process

Bi-Weekly Individual Work 1:

In the first Bi-Week, I joined the meeting to discuss our solar panel BOM, software design, and the specific future plan. The following flowchart is the one I created as an entire diagram system flowchart using the software, called Drawio:



The Team has had some updates since last semester. We were acquiring all of the parts for our capstone project. The electrical components have been ordered, however, we were waiting on ordering the mechanical components to see if we can find cheaper options or scrap metal from the machine shop. Furthermore, we discussed this as a team and with our client and we decided to not enter the competition held at Georgia Tech.

In the previous semester, we assumed that our Raspberry Pi would receive a signal for the timer to trigger burning the wire. However, after the discussion with the client, I figured out that they do not use HTTP and communication using the serial protocol for the MemeSat. Therefore, instead of building the implementation of the timer, I decided to use a hardware component, a 555 timer, to set a timer for burning the wire. I explained this to the rest of my teammates. For the implementation of the PiJuice, our own repository was created on GitHub. Once we receive the PiJuice, we will start working on software installation on Raspberry Pi with the PiJuice.

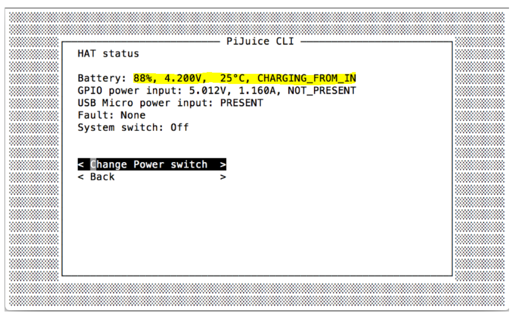
Bi-Weekly Individual Work 2:

In the second Bi-Week, Cole and I have made great progress on Electrical design:

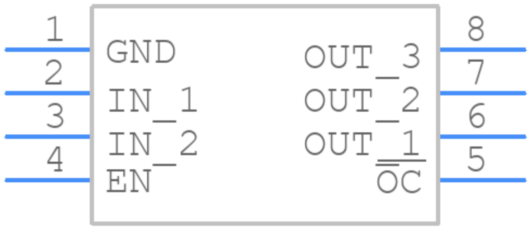
Testing/Assembly

All of the electrical components have been ordered and we are currently waiting for the technology to be delivered. The first test our team will conduct includes the testing of the Nichrome Wire. We ordered three different gauges of Nichrome Wire to test to see which ones burn the best with minimal current draw and time. We will hook up a DC generator to simulate the power going into the system and clock the time it will completely burn and look at the amount of current it will draw. The time is essential to maximum efficiency for the mechanical aspect. Regarding the current draw, this will affect the power drawn from the battery and we want to have the least amount of power drawn in order to have the capability to burn all of the systems. If the current draw is too high the battery will not be able to burn the 4 sides hooked with nichrome wire.

Once we dictate which Nichrome wire we will use, the circuit for the Solar Panels will be tested as well. The Solar Panels and the rest of the power system are being delivered and our game plan will be to assemble the system and test the power output. The solar cells will be lined up in series and then in parallel for each side. We will shine sunlight onto the panels and figure out the different orientations the CubeSat will be in and measure the power output from the panels. From this, we will gather more information regarding the power system of the solar panels. Furthermore, the PiJuice will be tested to see if we can get a Voltage and temperature reading from it. From this information, we will be able to tell which side of CubeSat is facing the Sun.



The Nichrome Wire Circuit will also be tested. The MOSFET switches will be put on a breadboard and given signals that will activate the switch and then the output pins will be connected to a Voltmeter. From the Voltmeter, we will be able to read if the output is correctly switching from two of the sides to the other two preventing an over-current draw from the Nichrome Wires.



For now, the current plan for testing should get us to the end goal of our project but this will be changed if we run into issues or think of more efficient methods of testing.

Updates of Circuitry

The Circuit updates include an increase of Nichrome Wire connections and restrictor diodes to limit current drawbacks. The sides will now be tethered by two Nichrome Wires each for more stability. However, this is not set in stone since we do have to test the current draw from these Nichrome Wires. Furthermore, there will be a slight change to the Solar Panels circuit as well. We have a fear of dark currents limiting the power flow of the solar cells. As a result, we will be testing each node of the solar panels with different configurations, as described above. To fix this possible issue, we will plan to put either Transistors or Schottky Diodes within the circuit to limit dark current.

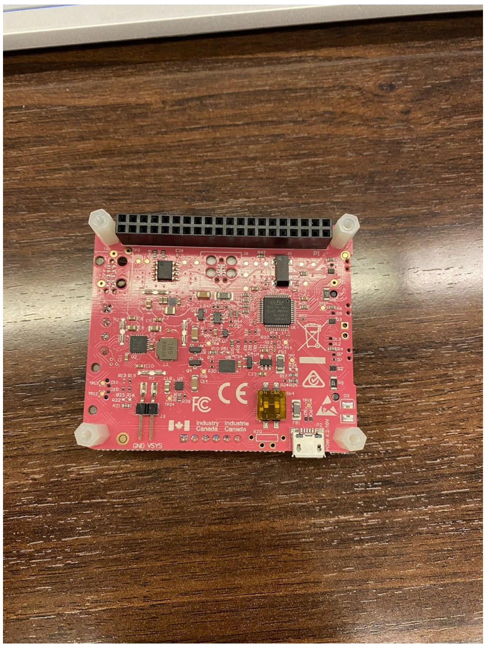
The circuitry will be placed on a PCB and the main components of the circuitry have not changed. However, after testing, simulations, and construction this could change.

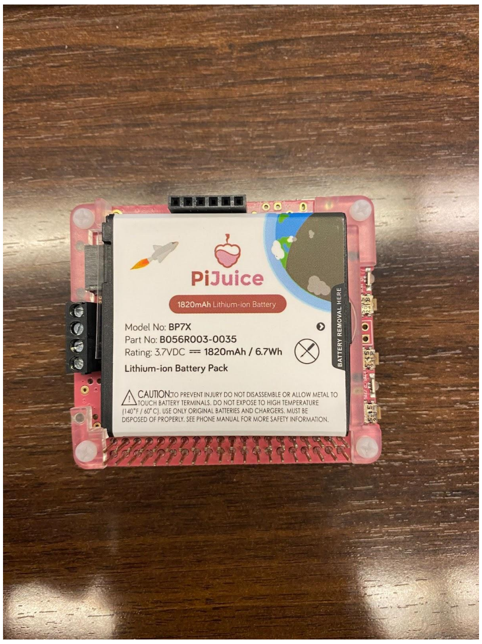
Bi-Weekly Individual Work 3:

This week, we received the Solar Panels, the Pi Juice, and the Nichrome Wires. I am only a software team member on this team, so I started to implement the codes for the PiJuice.

PiJuice

This piece of technology harnesses the output voltage from the solar panels and powers the Raspberry Pi. Throughout the first semester, we looked into the uses of the PiJuice and now we are able to test its functions. The testing will include measuring the voltage input and the temperature of the solar panels. Our goal is to see if we can relate the measured values to determine the orientation of the CubeSat. The picture below demonstrates the pinout and how the PiJuice fits onto the Raspberry pi.



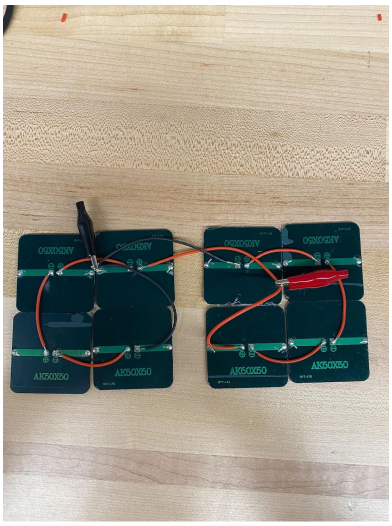


Bi-Weekly Individual Work 4:

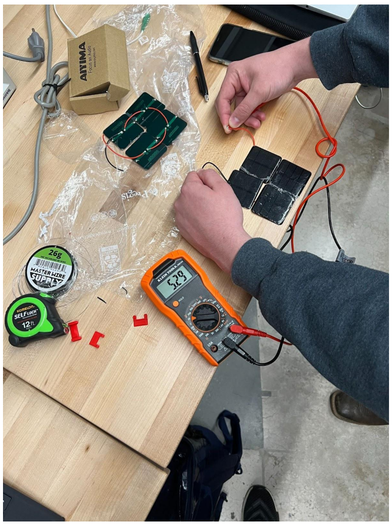
This week, I tested the electrical circuit with Cole.

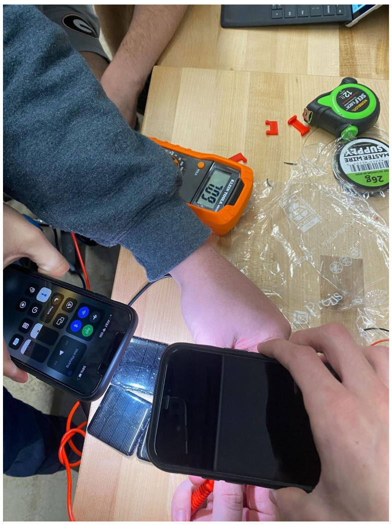
Electrical Circuit Testing - Solar Panels

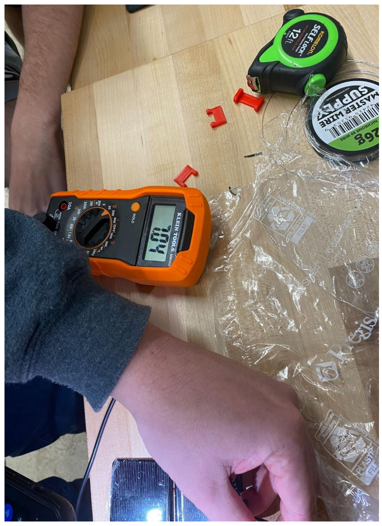
The electrical team wired the solar panels together to attempt to acquire a voltage output. The solar panels were wired, as seen in the picture below, with four panels in series with 2 groups of four in parallel making 8 cells total for one side. Our goal was to successfully test one side since the CubeSat will be facing the sun with a maximum one side optimally.



Furthermore, we tested the output voltage with base indoor lighting as well as an additional light source from a flashlight to try and increase the output voltage. This testing proved to be successful as seen in the Voltmeter below in the pictures. The Values include: Base = 5.29V / Additional = 7.04 - 7.09V.





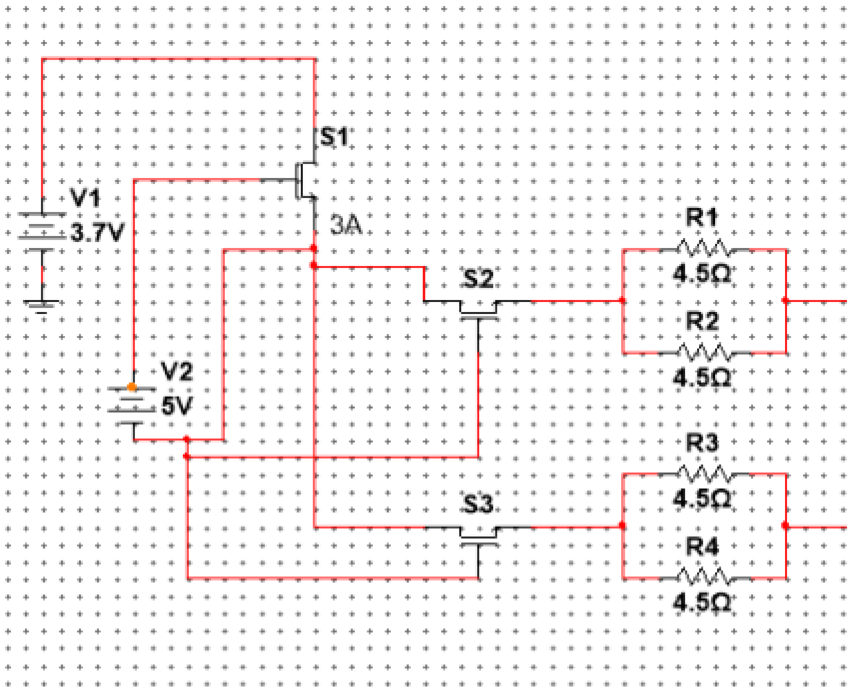


<u>Bi-Weekly Individual Work 5:</u>

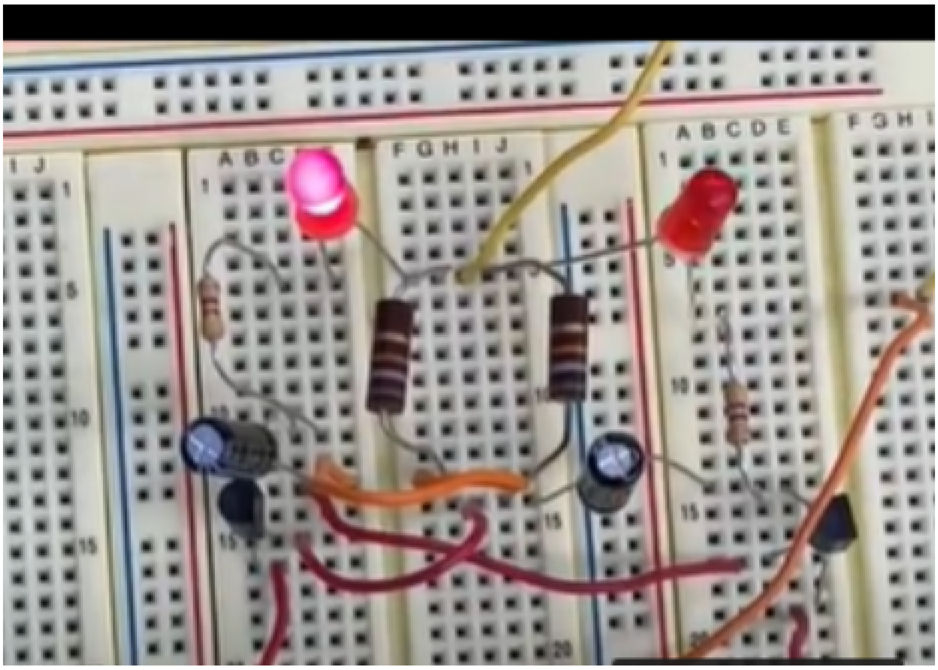
During the group meeting, Everyone was working on individual work. Cole was testing the Nichrome Wire. Aron was working on the Mechanical testing. Others were helping Cole. My main mission for this week was circuit simulation and completing the circuit analysis.

<u>Circuitry Analysis/Simulation</u>

The following figure is the rough sketch of the circuit I built on Multisim:



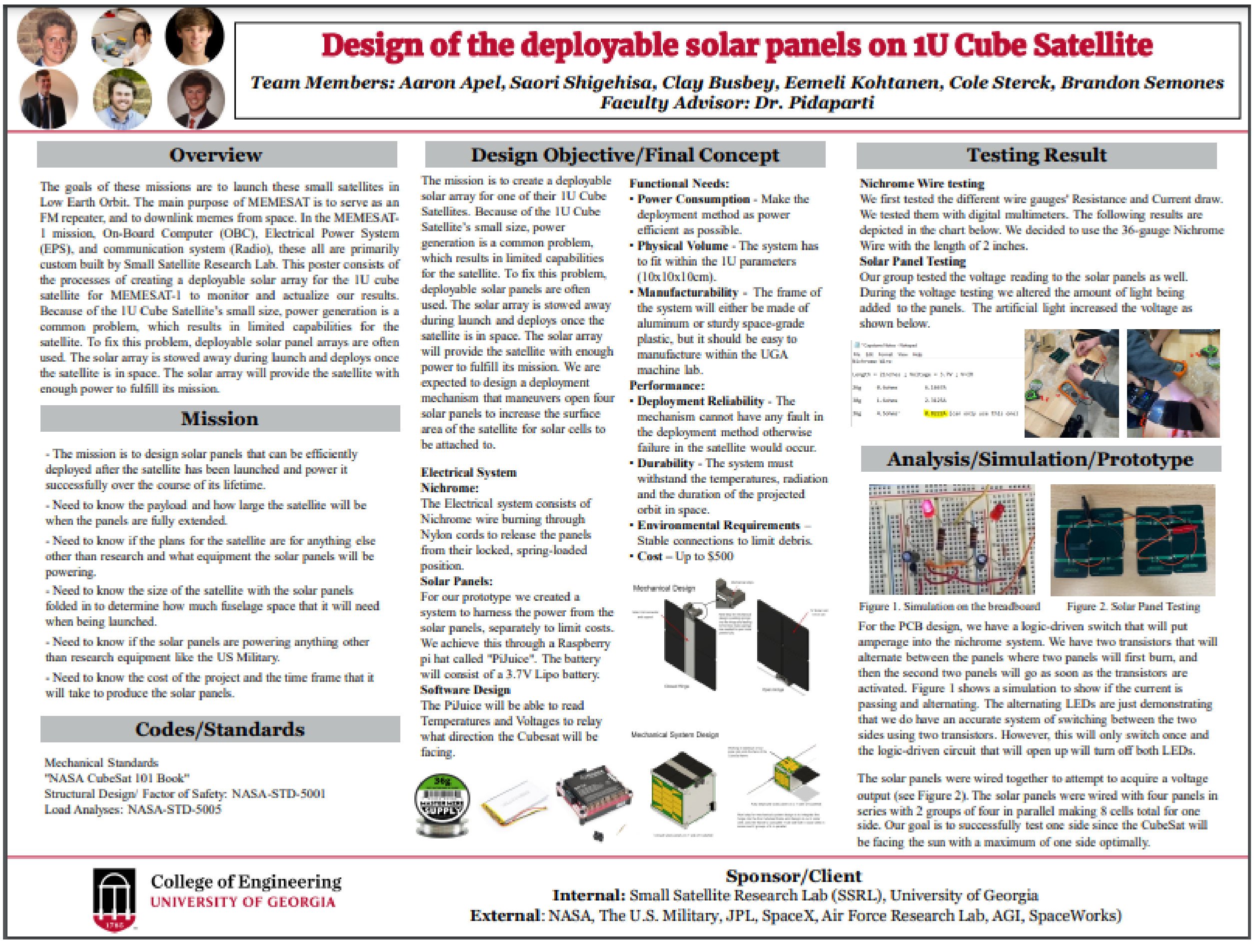
After the discussion with Cole, I came up with an idea that it would be cool if we can delay the timing of opening each solar panel. Therefore, Applying the knowledge that I obtained from the circuit class, I designed and tested the PCB design. For the PCB design, I designed a logic-driven switch that will put amperage into the nichrome system. The following design has two transistors that will alternate between the panels where two panels will first burn and then the second two panels will go as soon as the transistors are activated. This right here is just a rough simulation to show if the current is passing and alternating. The alternating LEDs are just demonstrating that we do have an accurate system of switching between the two sides using two transistors. However, this will only switch once and the logic-driven circuit that will open up will turn off both LEDs.



Another electrical teammate, Cole also liked this circuit design, and we decided to use my circuit design.

Bi-Weekly Indivisual Work 6:

Cole and I had 2 different types of drafts of the poster. Cole created a poster with a red-colored style, but everyone else agreed with using my poster draft. I have done 85% of the poster design as follows:



Because I have a language barrier, Cole and Aron mainly helped me out to finish it up to make it more professional. Clay also checked at the end.

Bi-Weekly Individual Work 7:

I have completed the implementation for the raspberry pi 4 and PiJuice and their settings. However, instead of using Raspberry Pi 4, we decided to use Arduino. When I tried to implement codes for PiJuice to display the voltage amount for the PiJuice, it did not detect the battery. Cole gave me another 3.7V battery and Voltage Source, however, “Communication Error” occurred no matter what. We eventually figured out that the PiJUice Hat was burnt. Therefore, we decided to use Arduino.

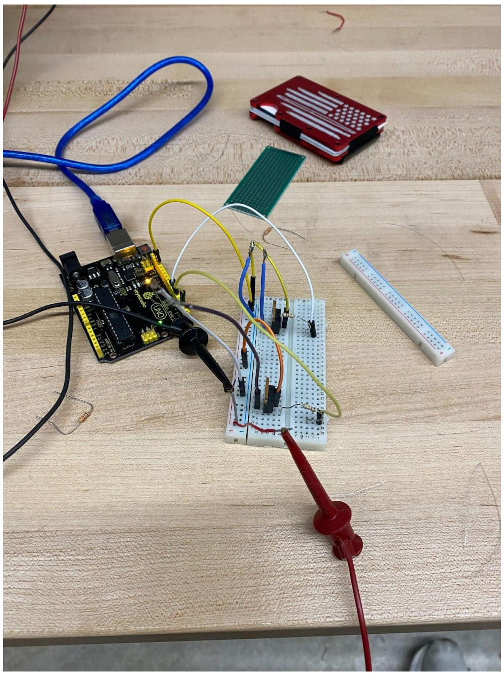


Figure 1

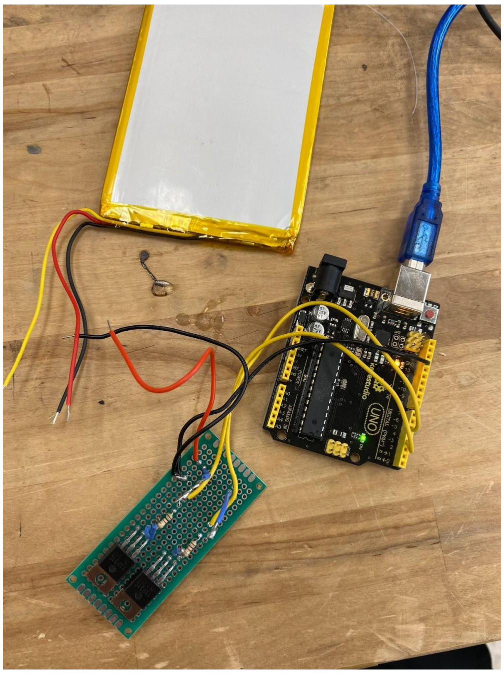


Figure 2

In figure 1 the electrical system is assembled on a breadboard along with an Arduino UNO. On the breadboard there are the following items:

- NPN Transistor (2)
- Nichrome Wire
- 1k Resistors

In Figure 2 the entire system is soldered to a perf board to make the system more solidified. The perf board is the more permanent version we will use in the final prototype.

The entire system is powered by the 3.7 Volt LIPO battery and has a maximum current draw of 0.6 amps due to the alternating system of the transistors.

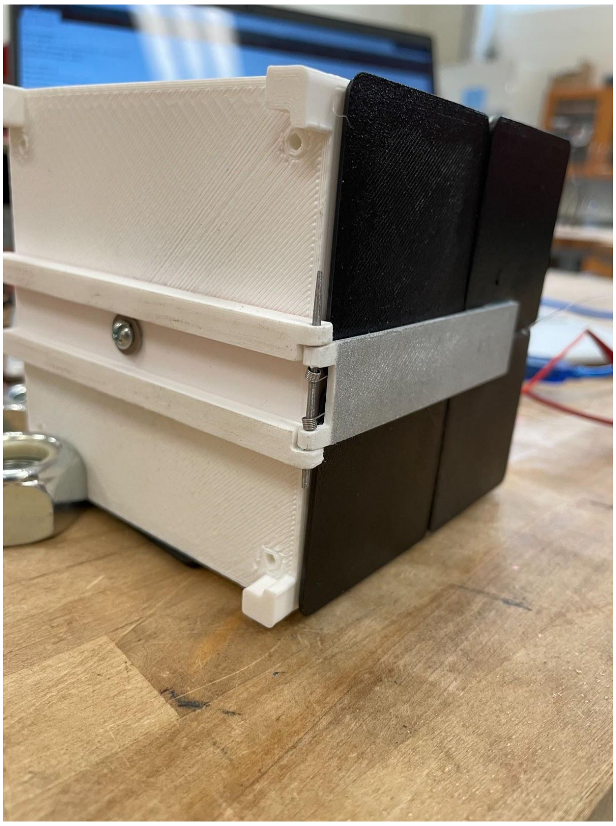
The following code is the implementation on Arduino:

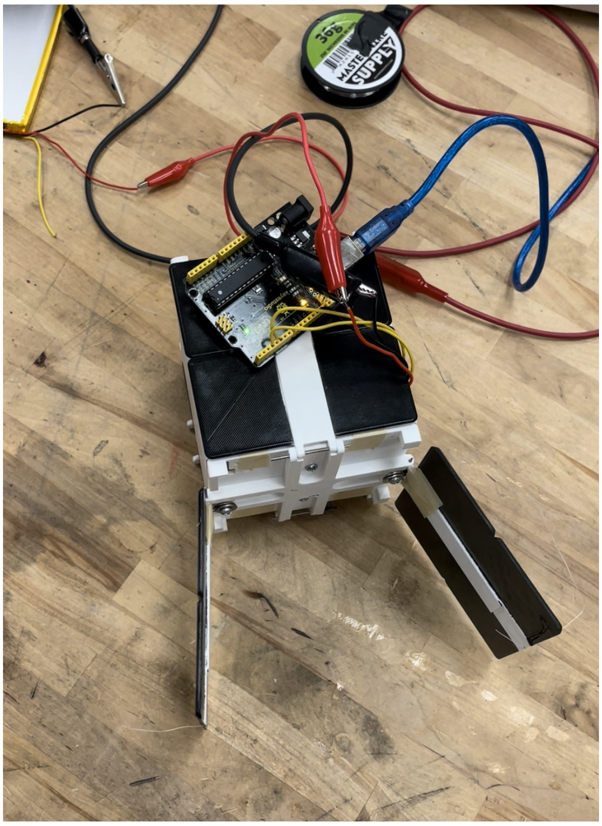
nichrome_test

```
int Nichrome1 = 3;
int Nichrome2 = 5;
void setup() {
  // put your setup code here, to run once:
pinMode(Nichrome1,OUTPUT);
pinMode(Nichrome2,OUTPUT);
}
void loop() {
delay(5000);
analogWrite(Nichrome1,255);
delay(5000);
digitalWrite(Nichrome1,LOW);
analogWrite(Nichrome2,255);
delay(5000);
digitalWrite(Nichrome2,LOW);
delay(10000);
}
```

Mechanical System

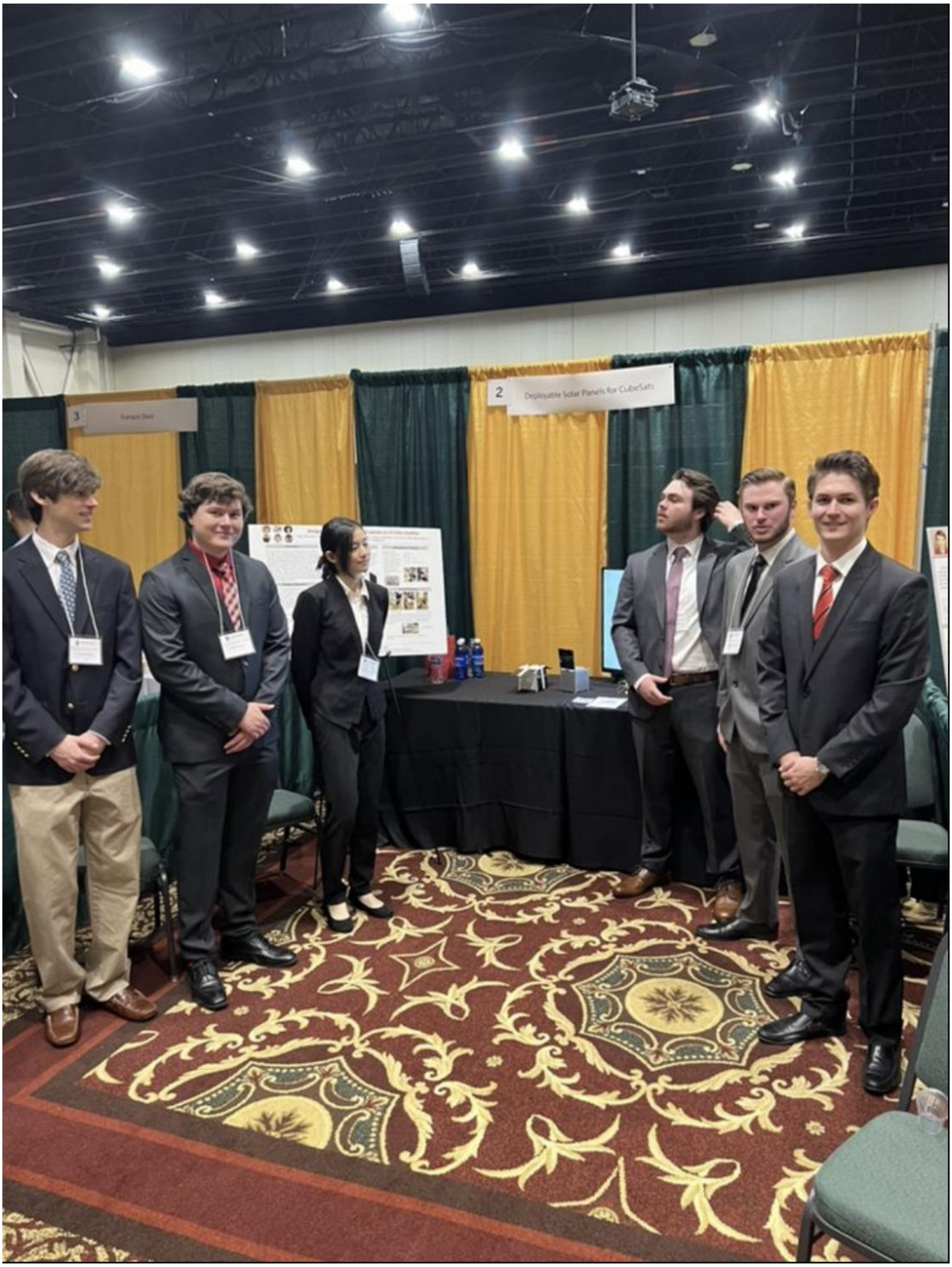
After we successfully make the electrical system worked, I joined the mechanical team and helped to make it work.





After printing and acquiring all of the necessary parts our team assembled the final prototype. First, it was by combining the 3D printed parts to create the mock satellite that would house the Arduino, battery, and surfboard. Then 4 sets of our solar panel design were made with their braces and hinges were attached to the 3-D printed satellite fuselage. The springs were then compressed and held down by the neochrome wire. The panels successfully deployed in our test when in a near-zero gravity position. Additionally, we worked with the machine shop to show what the true final satellite and solar panel design would look like when actually utilized.

After we made sure everything works fine, we met at the classic center and had a great time. Though I was so nervous to present to the examiners, I believe that we had a positive impression on them. The following is the picture with my teammates: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Deployable Solar Panels for CubeSats

The following picture is the certificate that I received at the classic center.

Bi-Weekly Individual Work 8 (last week of the semester):

I double-checked if we are still not missing anything, and I have checked with Cole and submitted the missing report and survey.

Conclusion

Throughout the capstone, I honed my software skills using Raspberry Pi 4 and python. We also used Arduino, so I also recalled my knowledge about C++. For the electrical engineering side, I had only a basic knowledge of circuits, but designed the circuit simulation and built it on the breadboard well. The circuit was used for our PCB board. Applying my previous knowledge and skills and searching on my own, enabled me to be ready for the skills needed for my future workplace.

This capstone project was really helpful. Especially, I am an international student, so when I start working in the workplace in the U.S, I have to know how to interact with people in the workplace is slightly different compared to my country. In the U.S, leadership is really important in the workplace. I certainly learned the skills necessary to succeed in my future jobs in the U.S.