UNL Aerospace Club

Advanced eXperimental Payloads

HASP Solar Cell Payload
Electrical Systems Report

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Objectives or Purpose:

This project is a payload to be launched on a high-altitude balloon as part of the High Altitude Student Platform (HASP) by LSU. Our intention is to use this balloon launch as a steppingstone towards building a cube satellite. Our payload will evaluate the efficiency of perovskite solar cells (PSCs) to prove they can perform as well in space as they do in lab conditions.

In 2023 the AXP team developed and deployed the first ever satellite built in Nebraska: Big Red Satellite 1. The team members involved have since graduated but have been a tremendous help this year assisting the current team in replicating their designs and offering suggestions.

Preliminary design:

The HASP provides power and a means to communicate with the ground, allowing our payload to stay relatively simple.

Our original plan was to keep our design very close to what BRS1 did, so we used an MSP430. For HASP and to collect data in test launches before HASP, we wanted to save data to a microSD, but the MSP430 does not have one built in. We decided it would be easiest to send the sensor readings from the MSP430 to the Teensy over UART, and have the Teensy save that data to its microSD. With that plan in mind, the MSP430 would be responsible for interacting with the HASP and taking readings from the solar cells and sun vector sensor. The Teensy would be responsible for listening to the data sent from the MSP430 and saving it to a microSD along with a temperature reading and a timestamp. The microSD acts as a redundancy in case of problems with HASP's communication systems. A visualization of the payload's systems is provided below (Figure 1).

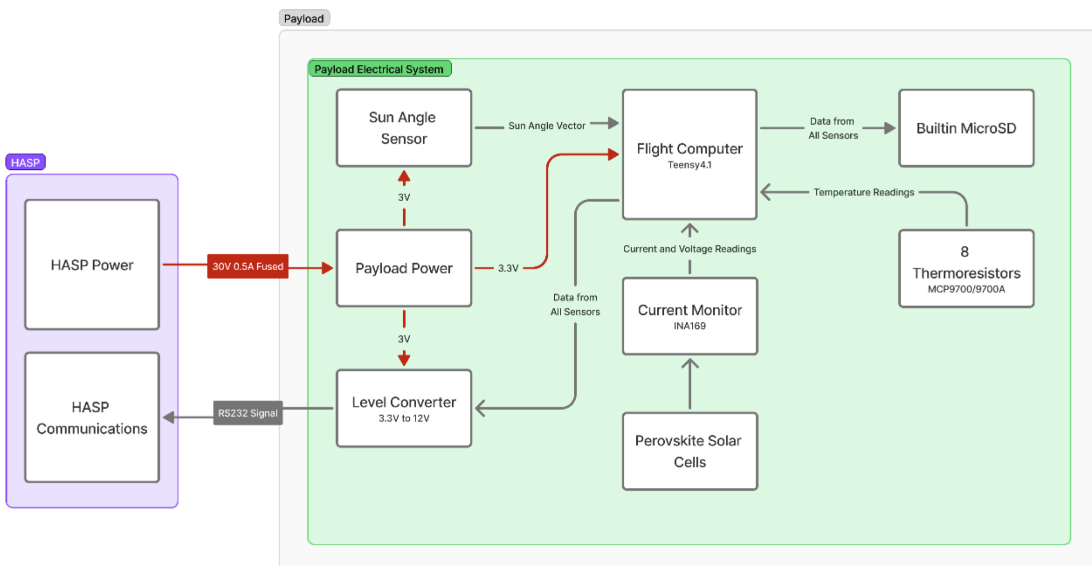

Figure 1 Payload Electrical Systems Schematic

The Teensy4.1 is the onboard flight computer for the balloon payload. It takes readings from the solar cells, thermoresistors, and sun angle sensor. All that data is stored on a microSD along with a timestamp based on the time in milliseconds since the Teensy powered on. The Teensy also sends the data to the HASP to be transmitted back to the ground.

Innovation Campus Test Launch

360 Video of the flight: https://youtu.be/nNtrG-YNFuc

On May 3, 2025 we had a successful test launch out of Innovation Campus where we were able to evaluate the effectiveness of the payloads systems. The launch went smoothly as there was very little wind. The payload weighed about 5lbs and we filled the balloon, so it had 11lbs of lift. The balloon reached an altitude of almost 100k feet (causing the GPS tracker to have multiple uint16 rollovers) and landed an hour south of Lincoln near Beatrice. The flight path is shown below (Figure 2).

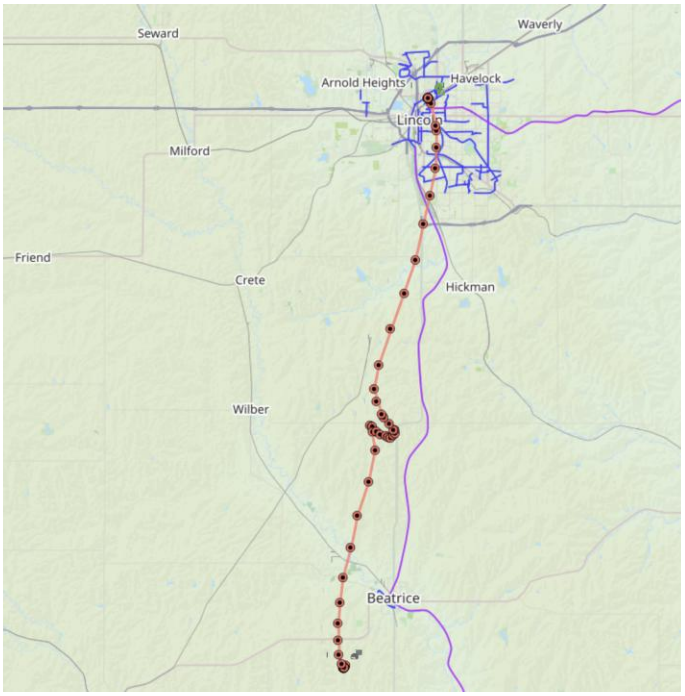

Figure 2: Test Flight Path

The Teensy and its code worked perfectly. In last year's test launch we recovered the payload, and the SD card was empty. It was a top priority to write data logging code this time around that was reliable, robust, and with redundancies.

The payload must have had a rough landing because we the top solar cell was cracked when we recovered it (Figure 4). Before the HASP flight, we will need to get new solar cells and improve their electrical connections because currently they are connected with aluminum foil and alligator clips. A mentor suggested copper tape.

The aluminum box holding the payload together held up well. Some of the 'L' brackets weren't quite the right shape so there are some unintended gaps between the panels. We will make a new aluminum housing before the HASP launch. The top of the housing has two loops for connecting the balloon, which will be removed since the hasp uses a different mechanism to secure the payloads.

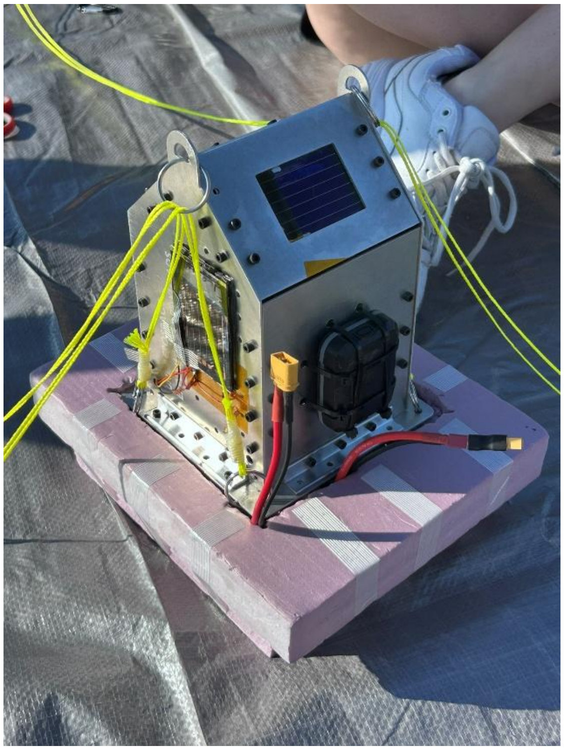

Figure 3: Payload Right Before Launch

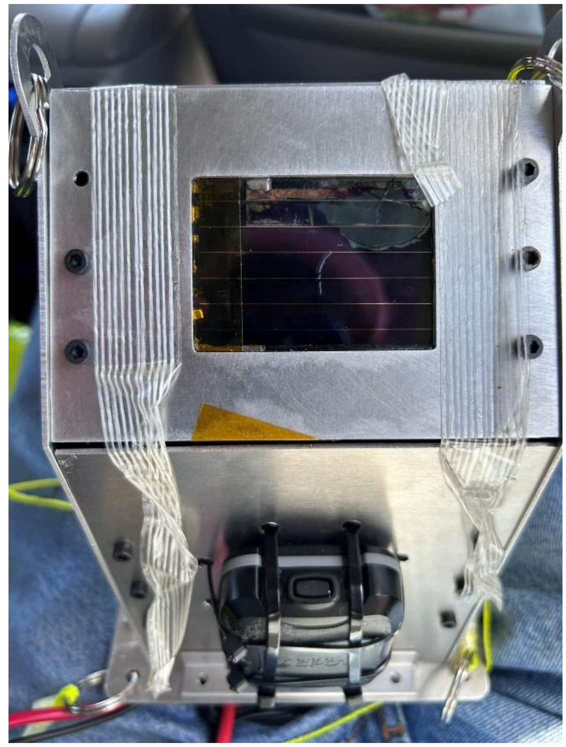

Figure 4: Payload After Recovery. Smashed Solar Cell

Figure 5: Payload Connected Balloon About to be Launched

Figure 6: Payload Recovery Site

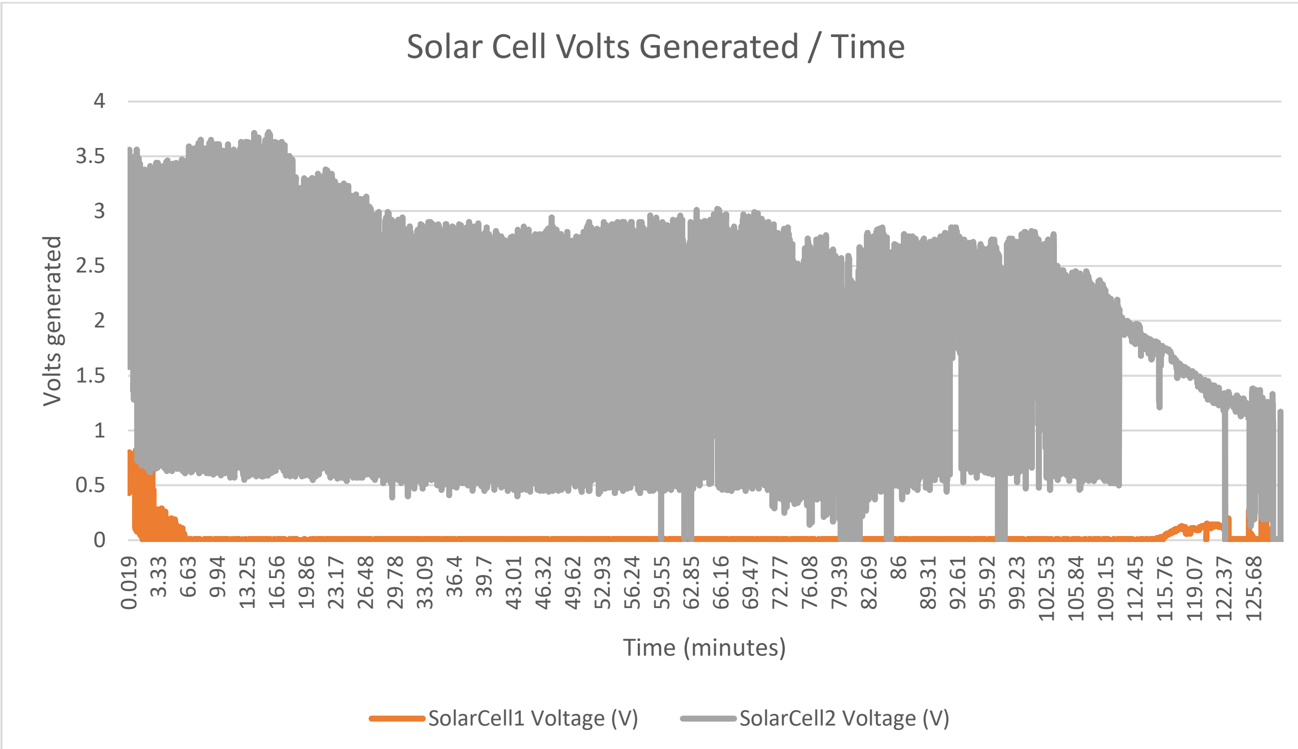

Figure 7: Graph of voltage generated by solar cells during Innovation Campus Test Launch on May 3, 2025

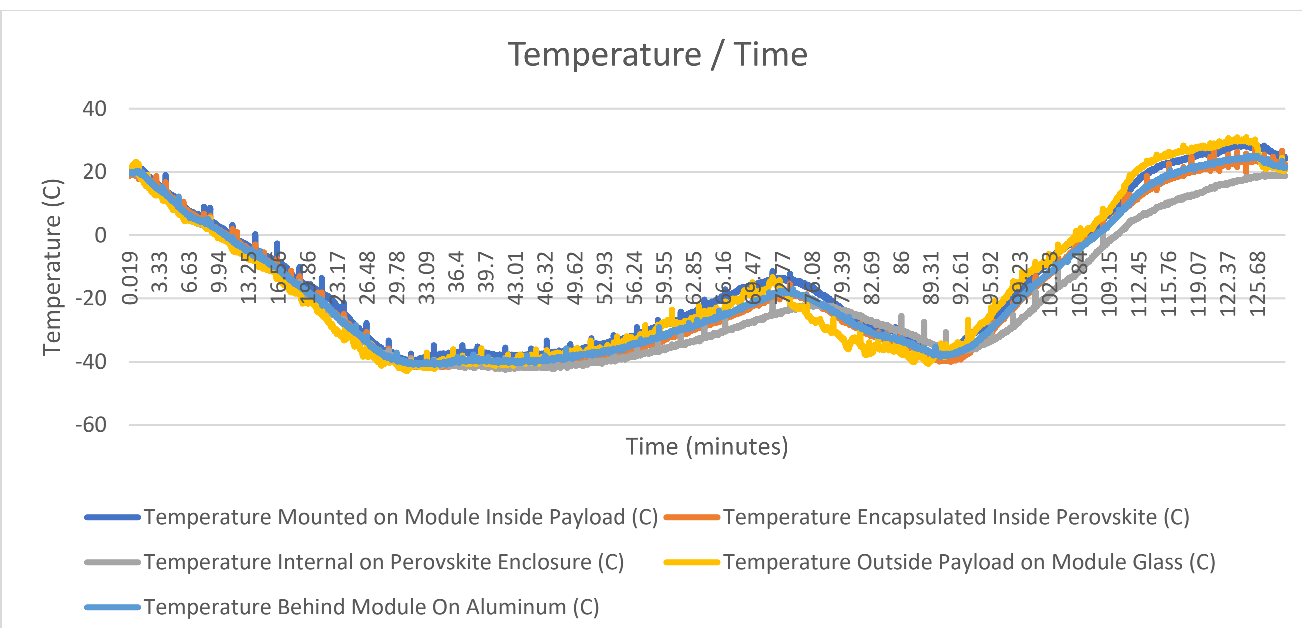

Figure 8: Graph of temperatures at different points on the payload during Innovation Campus Test Launch on May 3, 2025

The main computer for our payload was originally the MSP430 microcontroller (Figure 9). The schematic for this piece of hardware was left over from BRS1, and during our development, we struggled to get it to work. We decided that for HASP it was best to not use this board, sacrificing the curve tracers for simplicity with the deadline approaching. This computer was responsible for taking measurements from the solar cells as well as sun vector measurements from the sun angle sensor. The *Common-Anode Multiplexer* and *Curve Tracer/Resistor Ladder* in Figure 1 were for digitizing the readings from the solar cells. Our plan was to use the code from BRS1 in our system, but we had trouble getting it to work. The BRS1 GitHub repository is cited in the *Documentation* section of this report.

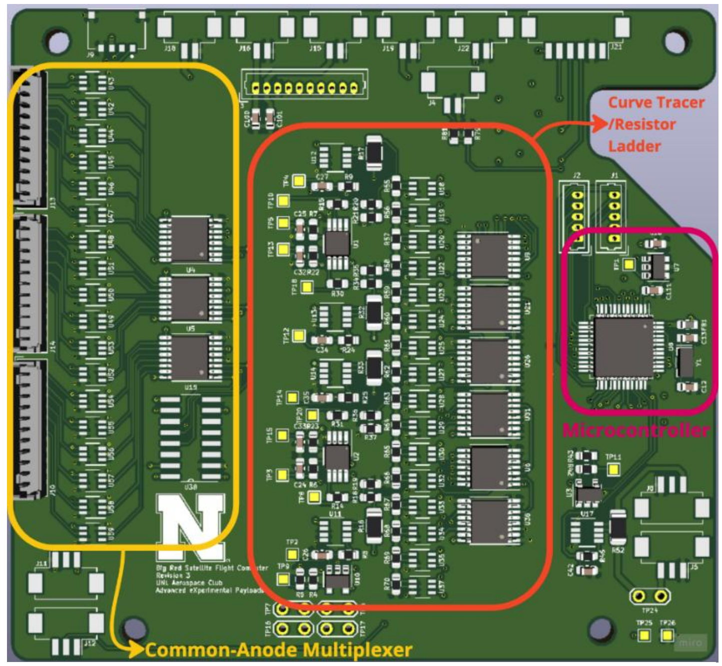

Figure 9: MSP430 flight computer. Not used in our payload.

Hardware schematic:

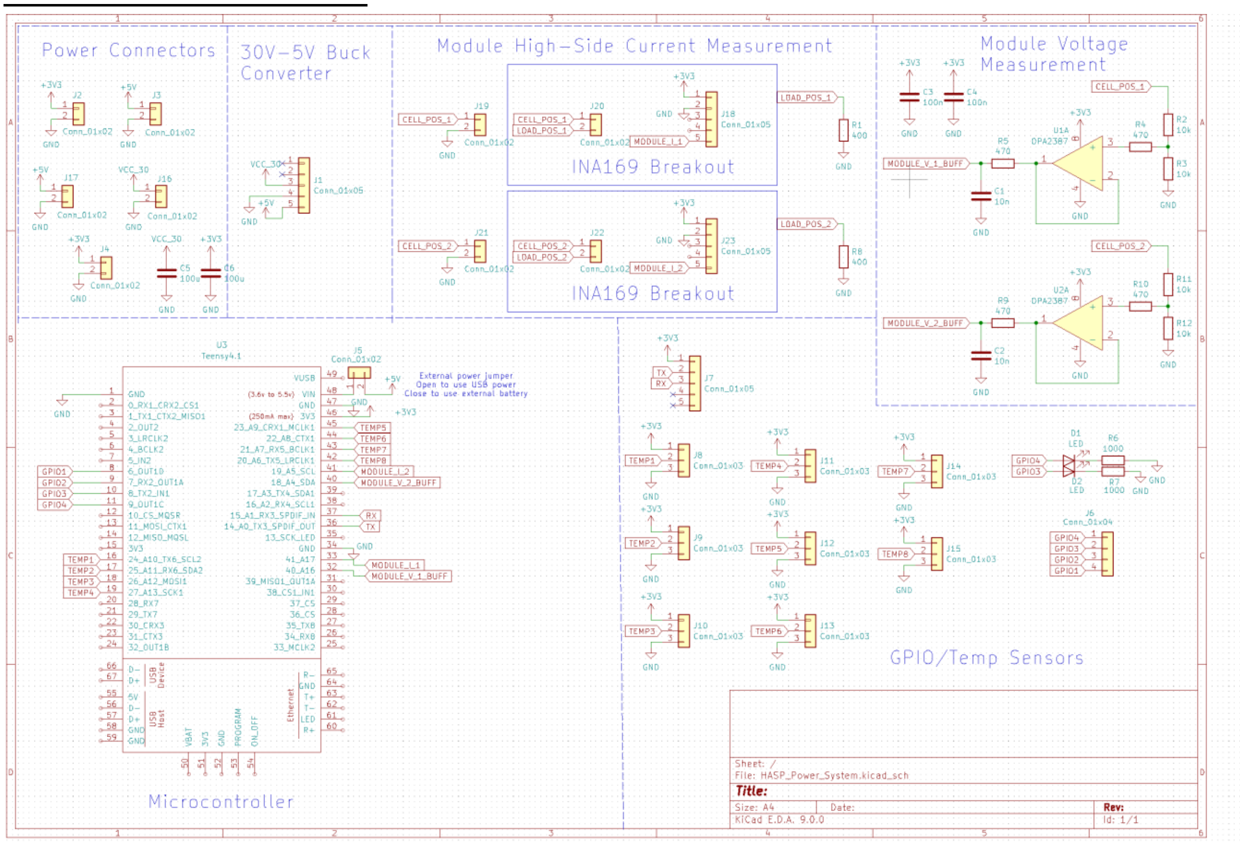

Figure 10: Hardware Schematic

Debugging:

MSP430

Since code for the old MSP430 flight computer gets uploaded indirectly through a dev board, we couldn't listen to the MSP430's Serial0 output through the Serial Monitor, making it difficult to debug the code for the flight computer. There was a point where we were unsure if it was sending anything through UART because the Teensy wasn't receiving anything from it. The method we found for debugging the flight computer was using a digital logic analyzer to inspect the UART output pin (Tx) of the MSP430. To prove that the board was even powering on, we set a digital pin to high and verified it was high with the digital logic analyzer. We soon were able to write the Tx pin and verify data was being sent through it.

Testing Methodology or Results:

Before the test launch, we performed an overnight test where the payload was left powered on. Our goal was to verify that there were no problems with memory filling up, or something causing the board to restart. We can tell how many times the board restarts by counting the number of files created on the SD card. We counted only one meaning nothing caused the Teensy to restart. The overnight test also helped to ensure the thermometers and solar panels weren't getting any interference because the room they were stored in had a mostly consistent temperature and amount of light. Below (Figure 11) is a graph produced during the overnight test showing the temperature and solar panel voltage readings over time. We concluded the test was successful because the graphs were mostly flat.

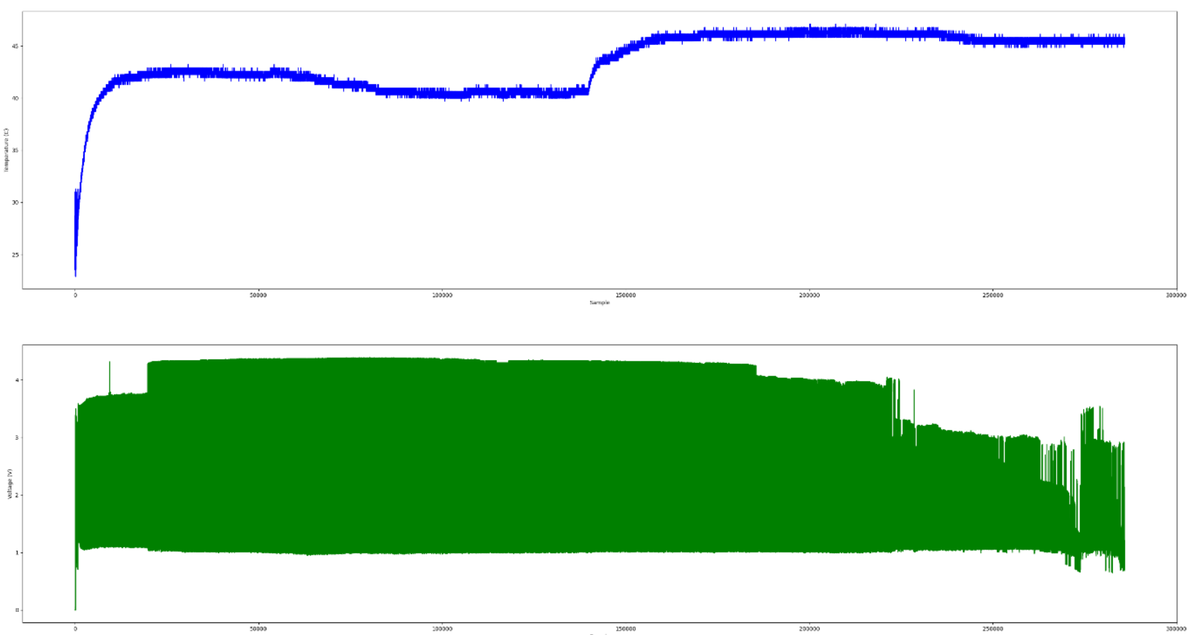

Figure 11: Overnight test results

The top graph shows the temperature in Celsius over time. The bottom graph shows the voltage generated by the solar cells over time.

Honors Contract Conclusion:

This project gave me an opportunity to use what I learned in CSCE 336 outside of the classroom to do some real science. I got experience with Teensy4.1 and MSP430 teaching me how different boards are tailored to specific tasks. I was introduced to creating custom PCB's which I plan to do more of over the summer for my own projects. I gained a better understanding of UART, I2C, and SPI. Making design decisions myself about which communication system to use gave me a more intuitive understanding of each one's strong suits. I created new code and refactored old code into reusable libraries to make the work for future AXP programmers easier. I am signed up to go to Texas this summer for our payload's integration with the HASP launch system. I look forward to improving our payload and hopefully working towards a career in embedded systems.

Documentation:

Big-Red-Sat. (n.d.). *GitHub - Big-Red-Sat/Big-Red-Sat-1: This repository contains the designs for the Big Red Sat-1, a 1U CubeSat examining the performance of perovskite solar cells in low earth orbit.* GitHub. https://github.com/Big-Red-Sat/Big-Red-Sat-1

Cerulli, N. (2023, April 28). *Perovskites: Finding a foothold for thin film solar*. Cleantech Group. https://www.cleantech.com/perovskites-finding-a-foothold-for-thin-film-solar/

MCP9700 Thermoresistor Datasheet https://ww1.microchip.com/downloads/en/DeviceDoc/20001942G.pdf

Teensy4.1 Datasheet https://www.pjrc.com/store/teensy41.html

MSP430 Datasheet https://www.ti.com/product/MSP430FR5969?keyMatch=MSP430FR5969&tisearch=universal_search&usecase=GPN-ALT#tech-docs