ENGINEERING PORTFOLIO

Matthew MacGregor

(360) 325-1779 | mrmacgre@usc.edu | www.linkedin.com/in/matthew-r-macgregor

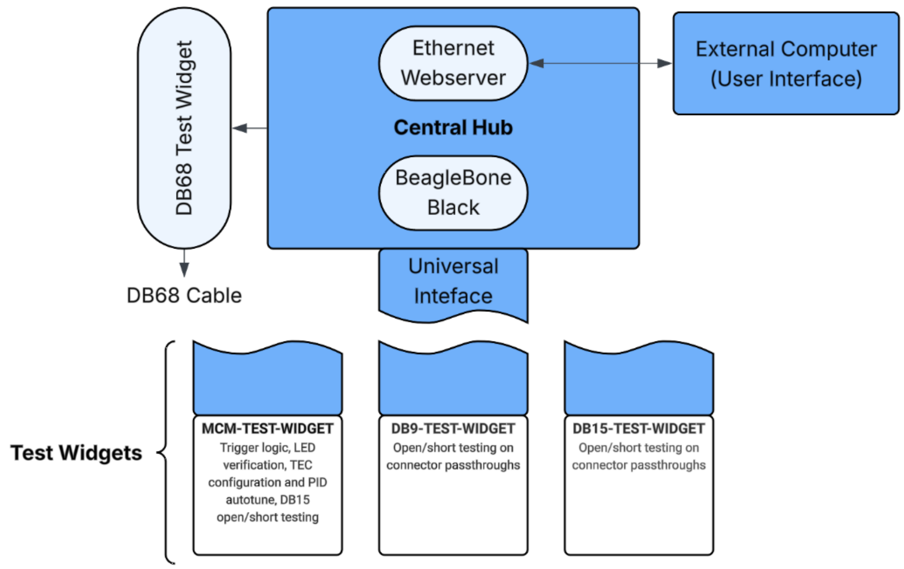
Table of Contents:

Internship Experience

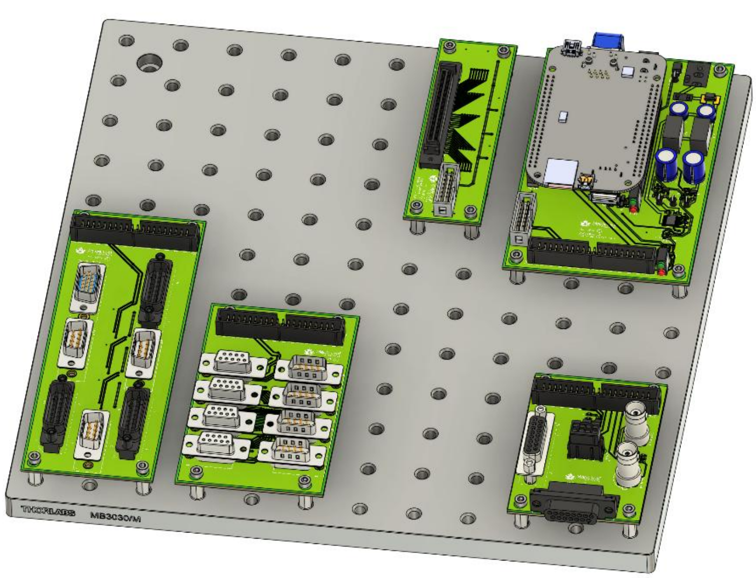
Electrical Engineering Intern (Maple Leaf Photonics)

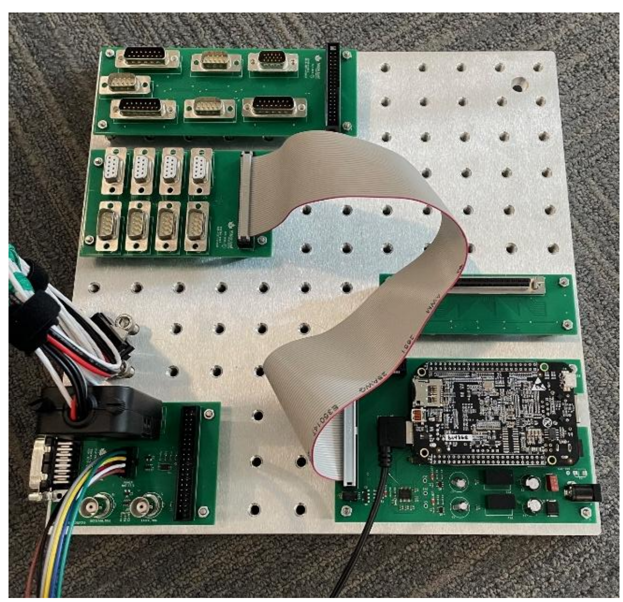
During my internship at Maple Leaf Photonics, I designed a modular PCB testing tool to improve product reliability, provide Quality Assurance records, and reduce test/assembly time.

The system architecture is shown here, consisting of a central hub running a webserver on a BeagleBone Black, a universal interface for connecting to modular test 'widgets', and individual widget boards with specific testing hardware. During my internship, I designed tests for a Peltier module controller with trigger inputs and LEDs, as well as two connector passthrough boards that required open/short testing on every signal line. In addition to the specific testing hardware required for these three boards, I ensured my architecture was expandable and future-proof to support further development and additional test widgets.



Shown below is the system CAD (with circuit schematics, PCB layouts, and mechanical assembly all done in Fusion 360 with my ownership), as well as the final physical product:

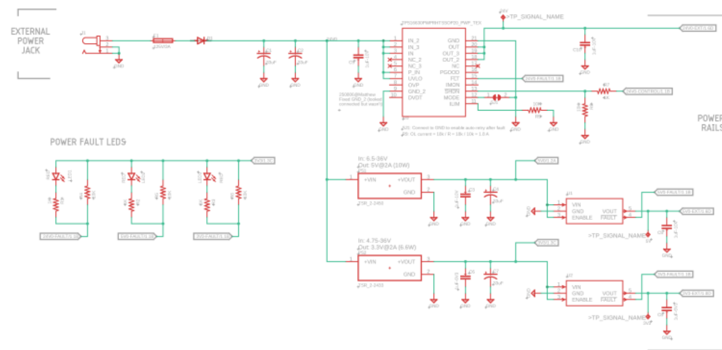


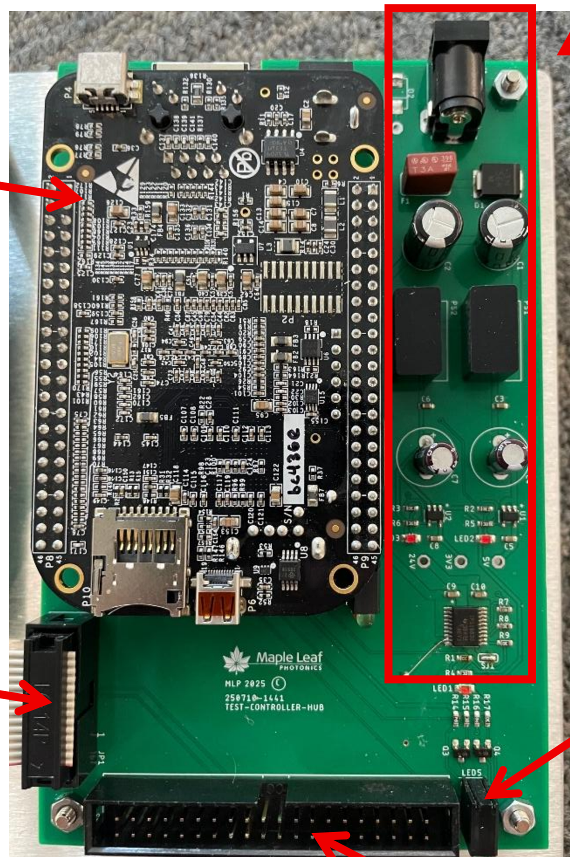


In addition to a BeagleBone Black for software, the TEST-CONTROLLER-HUB consisted of power distribution circuitry, LED status indicators, and universal connectors for the widgets.

Power Distribution:

ESD protection, fuses, and power regulation chips to distribute the 24V input into 5V and 3.3V outputs with fault indication.



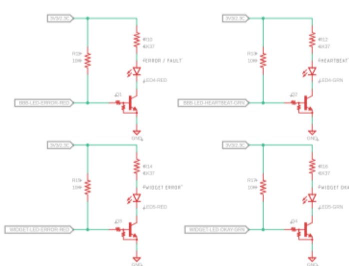


BeagleBone Black:

Single-board Linux computer for running the test software and hosting a webserver.

Status LEDs:

Provide information about the boot status of the BeagleBone and the state of a connected widget.

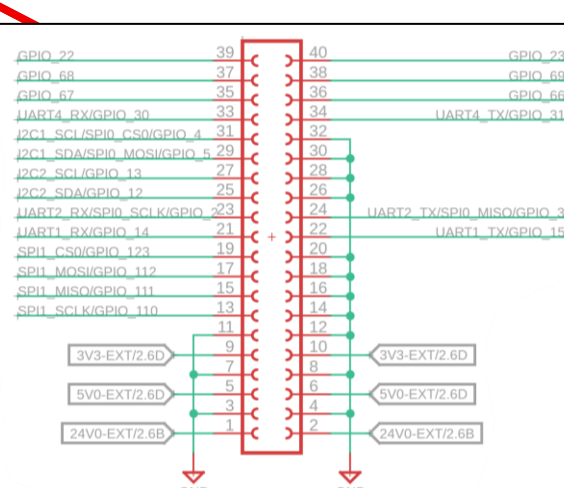


DB68 Test Widget Interface:

Provides a permanent connection for the DB68 test widget, which interfaces with 68-pin connectors used on many of Maple Leaf Photonics' PCBs.

Universal Interface:

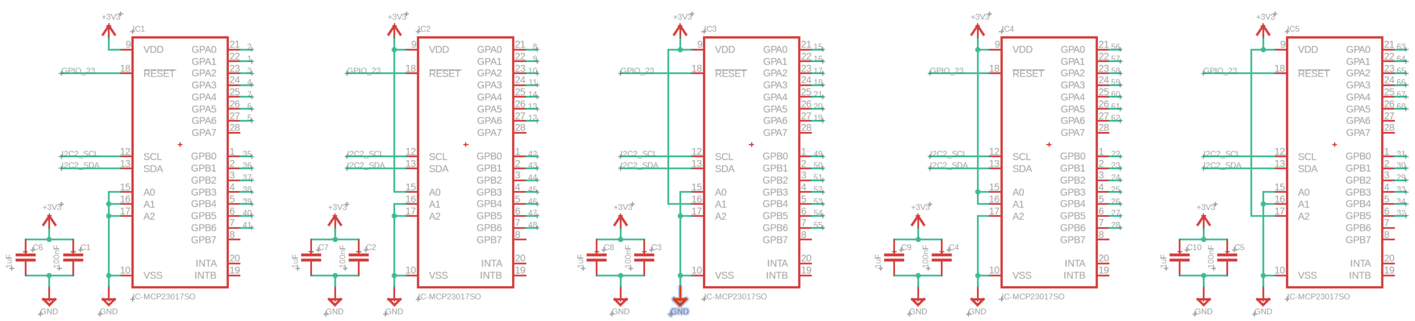
40-pin connector to carry a variety of communication protocols (I^2C, UART, SPI, GPIO) and power to widget PCBs.

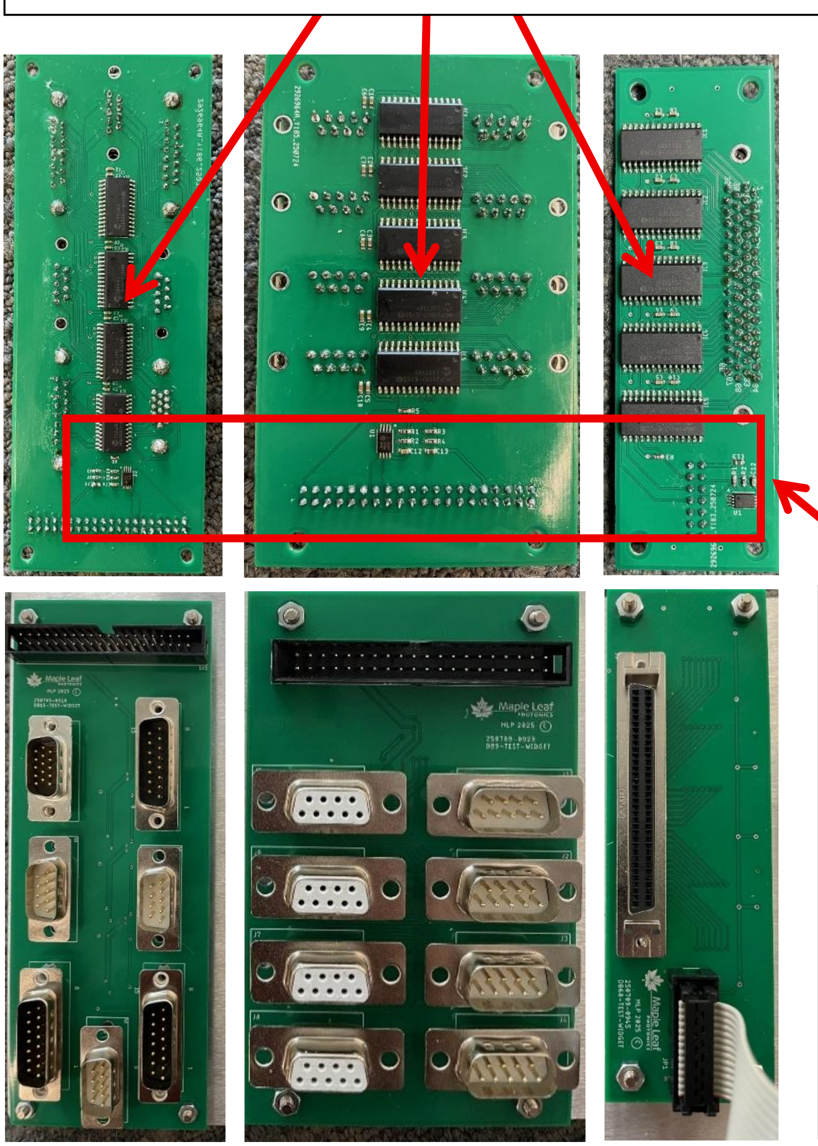


Since two of the boards I designed tests for (and many future ones) are simply connector passthroughs, I developed a common architecture using MCP23017 I/O expanders. These are routed to every pin of the connectors, which mate with corresponding connectors on the Devices Under Test (DUTs), allowing continuity between signal lines to be checked.

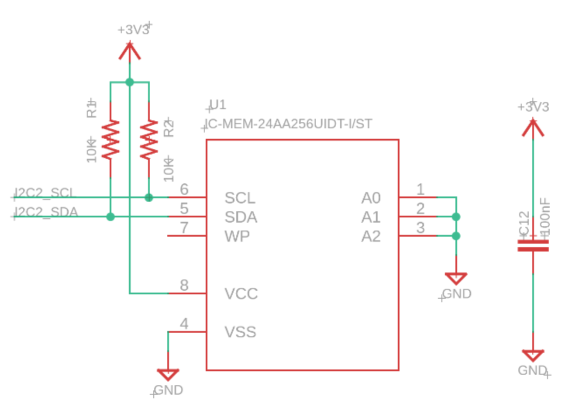
The DB9-TEST-WIDGET, DB15-TEST-WIDGET, and DB68-TEST-WIDGET use this design to test signals on various combinations of DB9, DB15, and DB68 connectors. Additionally, each widget has an I^2C EEPROM and supporting hardware that identifies the board to the central hub.

I/O Expander Array with Decoupling Capacitors and Pin Fanouts:

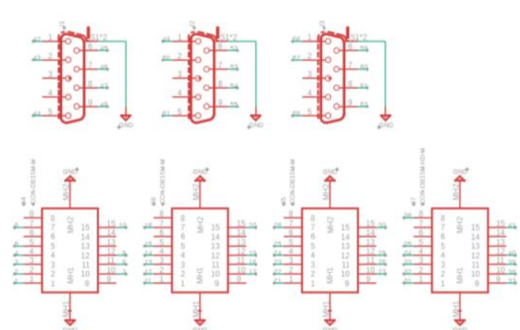




EEPROMs and Supporting Hardware:

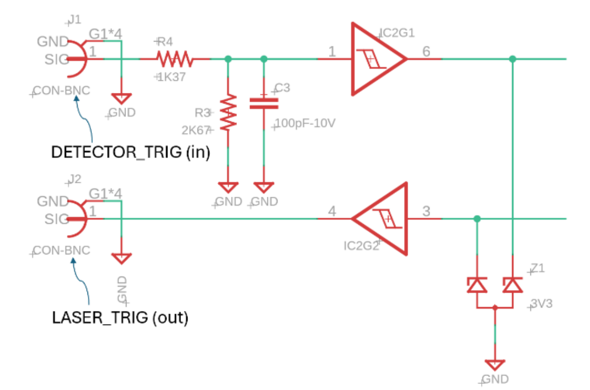


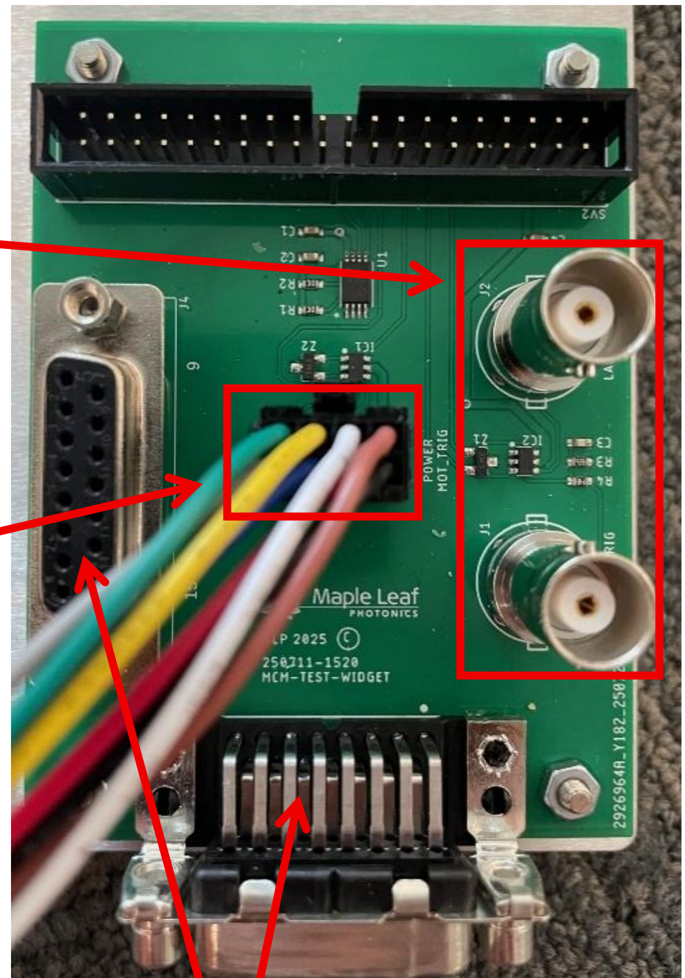
Connectors on top side of test widgets directly interface with the connectors on the DUTs. Each widget also has a connector for the universal interface.



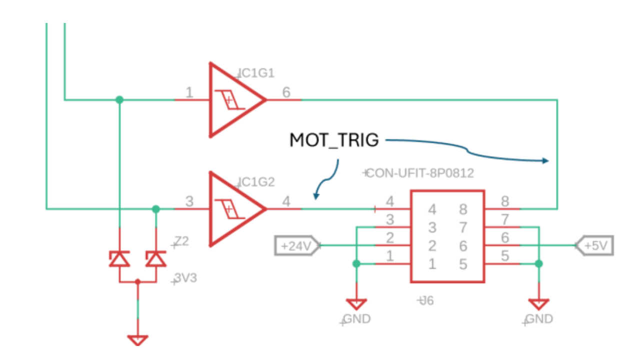
The most functional test widget I designed was the MCM-TEST-WIDGET, which connected to a thermoelectric controller PCB with LEDs and logic triggers. Testing involved sending inputs to each trigger and checking the output, verifying LED functionality, and configuring the TEC-1091 thermoelectric controller attached to the DUT. To configure and tune the TEC-1091 via software on the BeagleBone black, as well as perform open/short testing on the DB15 connector that interfaces with the thermistors and Peltier module, a USB cable could be connected from the BeagleBone black to the TEC. The widget also had its own EEPROM for identification, preventing the technician from running mismatched test code and risking damage to the boards.

BNC Trigger Connectors:



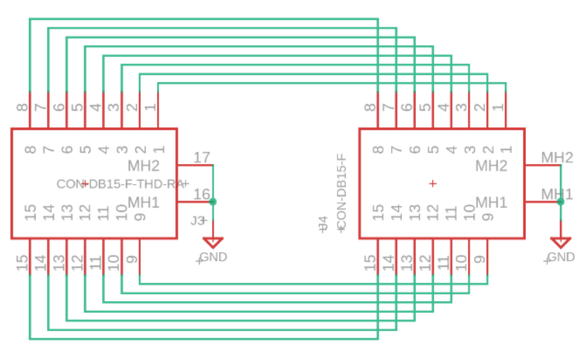


Power and Motor Triggers:

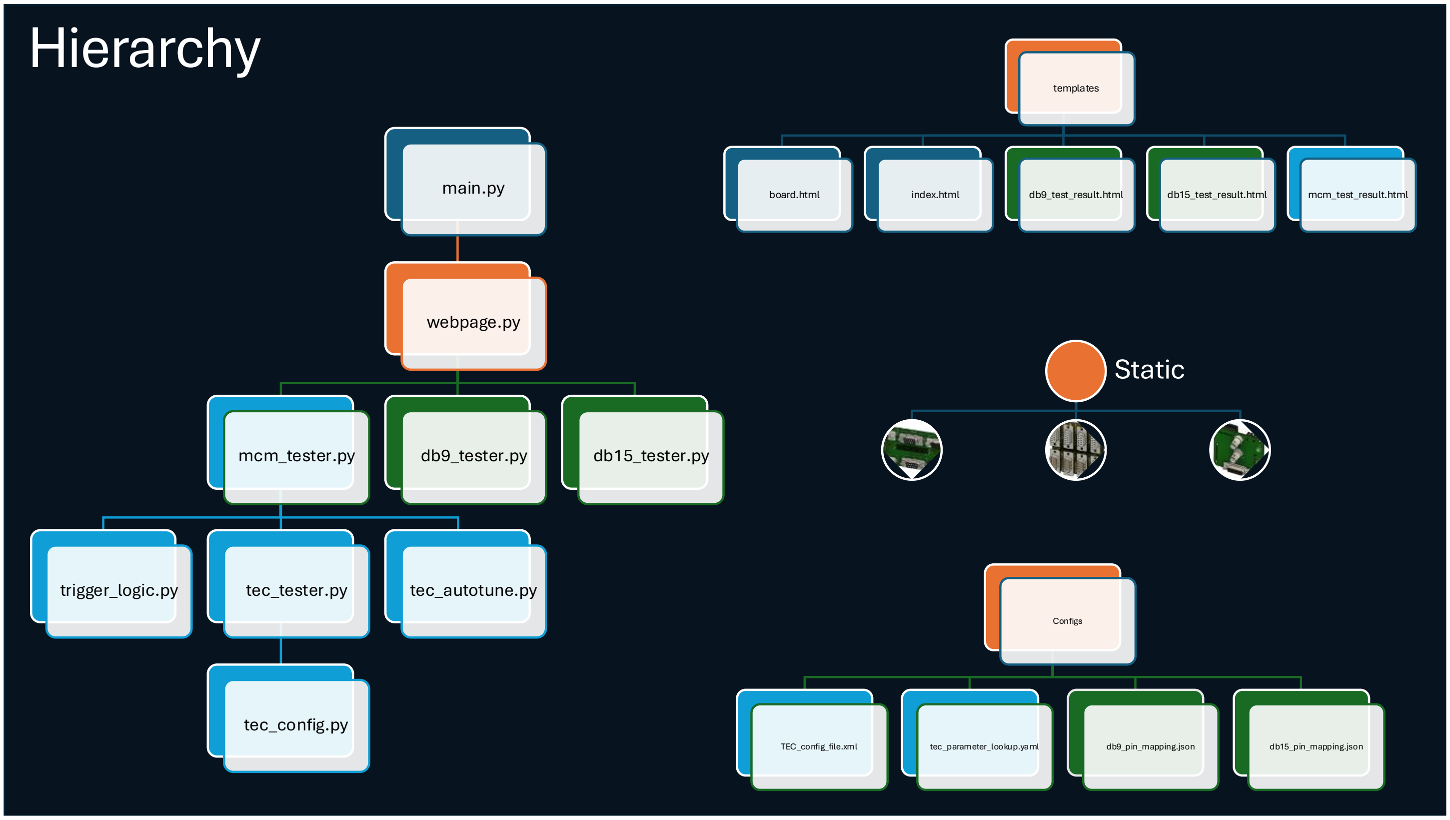


DB15 Passthrough:

Two DB15 connectors mapped directly to each other, allowing configurable calibration circuits, consisting of thermistors and Peltier modules, to be attached to the test widget for PID autotuning and configuration of the TEC-1091.

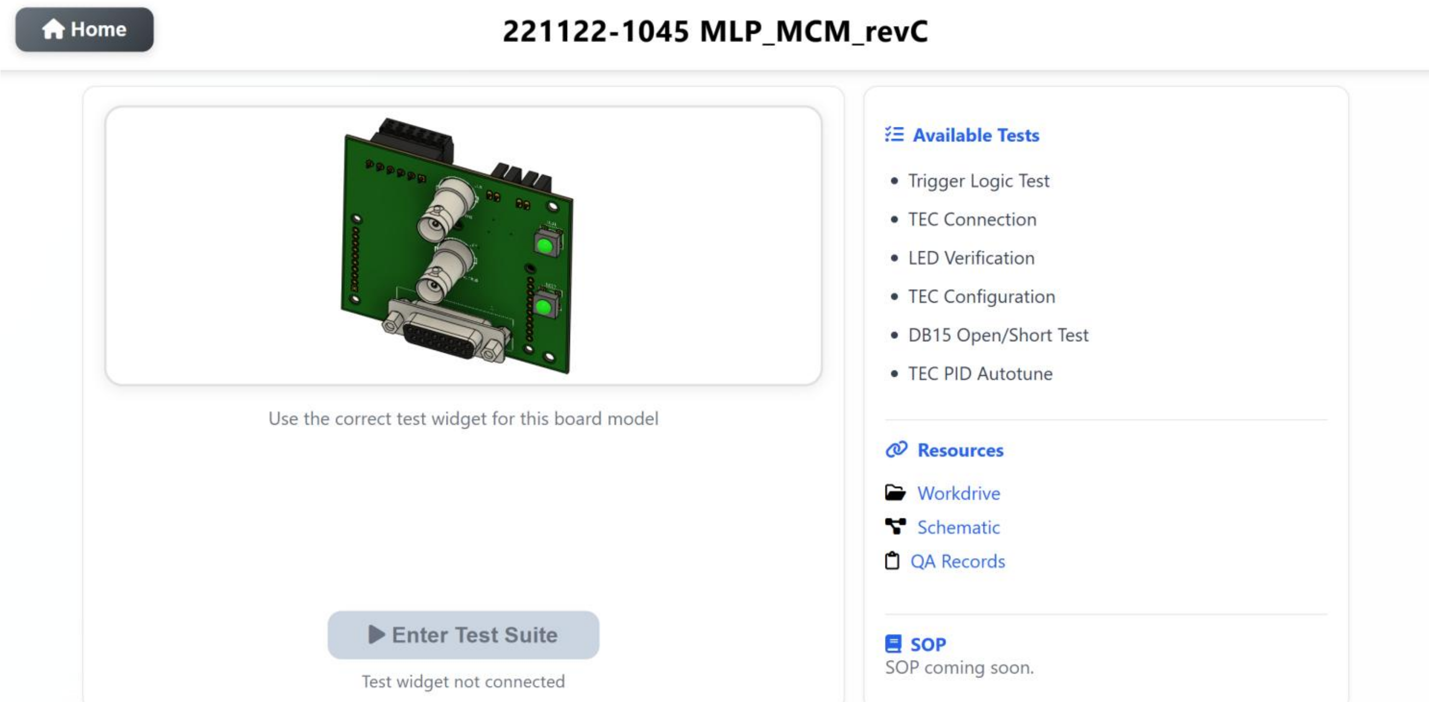


Finally, I wrote Python code to perform the hardware tests and host a Flask-based webserver. The overall hierarchy of this code is shown here, with a main file that runs the central webpage and individual testing pages for each widget. There are also html templates, images, and various configuration files for pin mapping and TEC-1091 parameters.

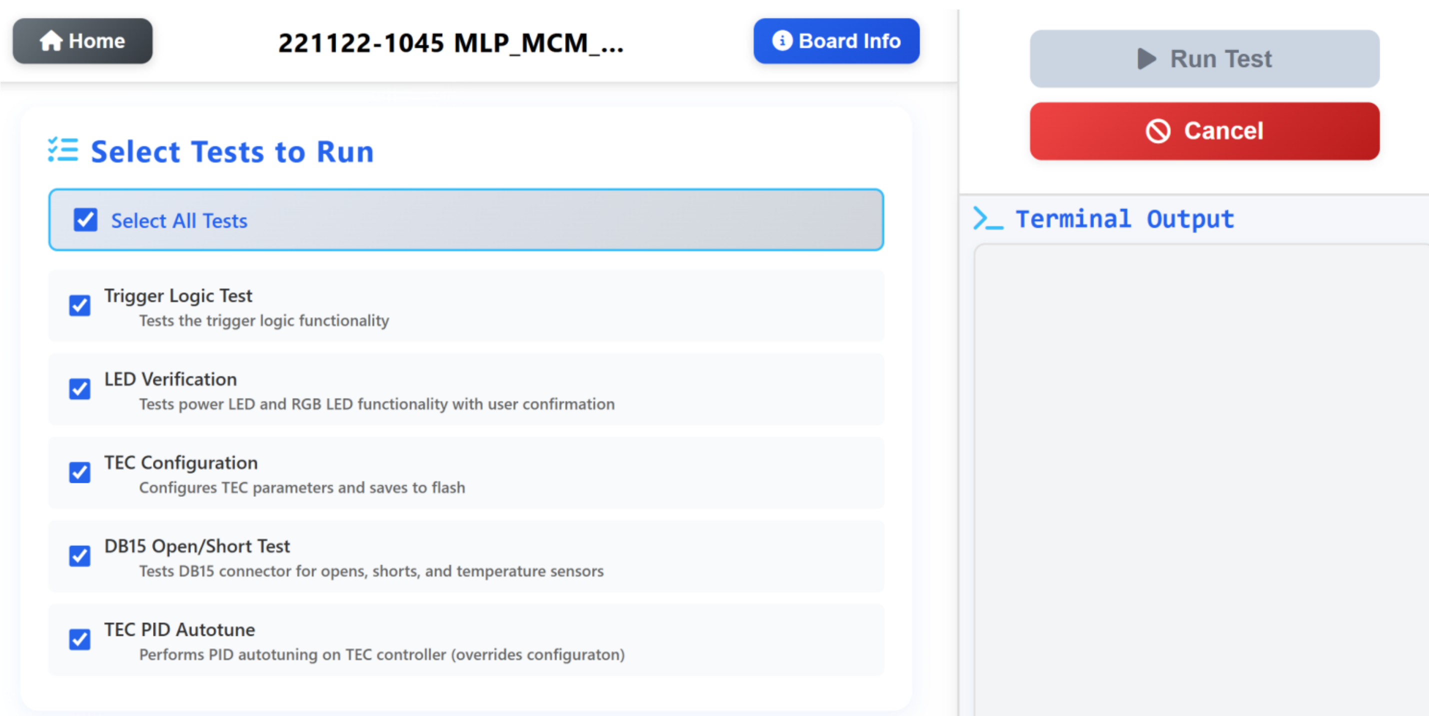


As for the webpage itself, a technician connecting to the BeagleBone Black over USB would first see the following page with a list of available PCBs to test:

When a board is selected, a submenu opens for that specific board, allowing the technician to navigate to documentation, QA records, and the testing page:



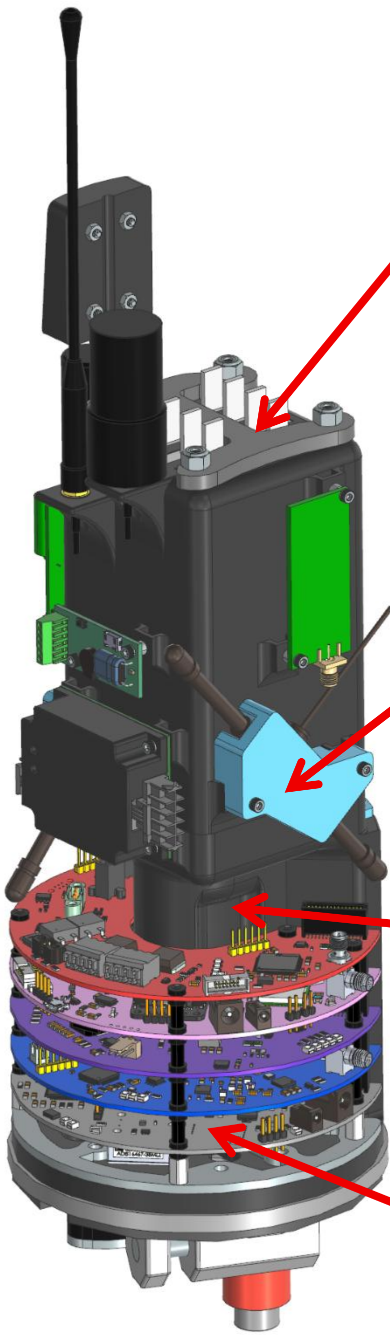
After entering the test suite (which is only allowed when the correct EEPROM is identified), the technician sees a selectable list of tests, a control panel, and a place for terminal outputs to be displayed with test results and debugging information:



USC Rocket Propulsion Laboratory

Avionics Structures CAD

My primary involvement with the USC Rocket Propulsion Laboratory is the Avionics Structures team. Shown below is the Siemens NX CAD of the 3D-printed avionics unit for our current vehicle, which I worked on with other members. As one of the Avionics Structures REs for launch, I have ownership for many of the designs/modifications to the components, most of which were done with the intent of reducing volume and streamlining integration. My major contributions are noted below, with additional elaboration for more impactful designs on the following page.



Carbon Fiber Battery Cover:

Replaced the old 3D-printed design with a sliding carbon-fiber battery cover that improves structural integrity and reduces integration time.

Magnetometer Mount:

Designed a new mount for a small external magnetometer, ensuring it was kept far from metal, RF cables, and other electromagnetic noise.

Angled Dipole Antenna Covers:

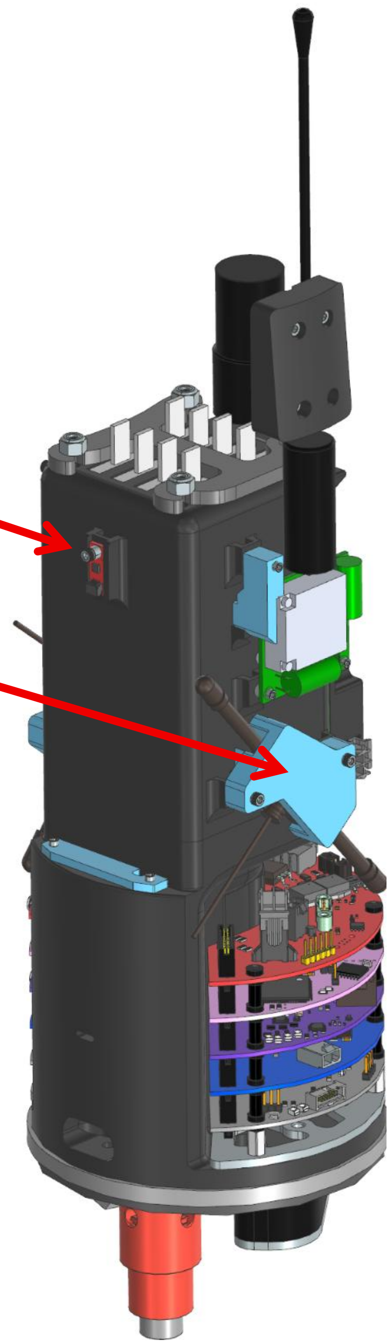
Redesigned the mount/cover to hold dipole antennas at a 50° angle instead of 45° - reducing unit footprint and enabling a clean fit in the nosecone.

Cable Channels:

Created grooved channels on the section behind the PCBs to make antenna cable routing easier during unit integration.

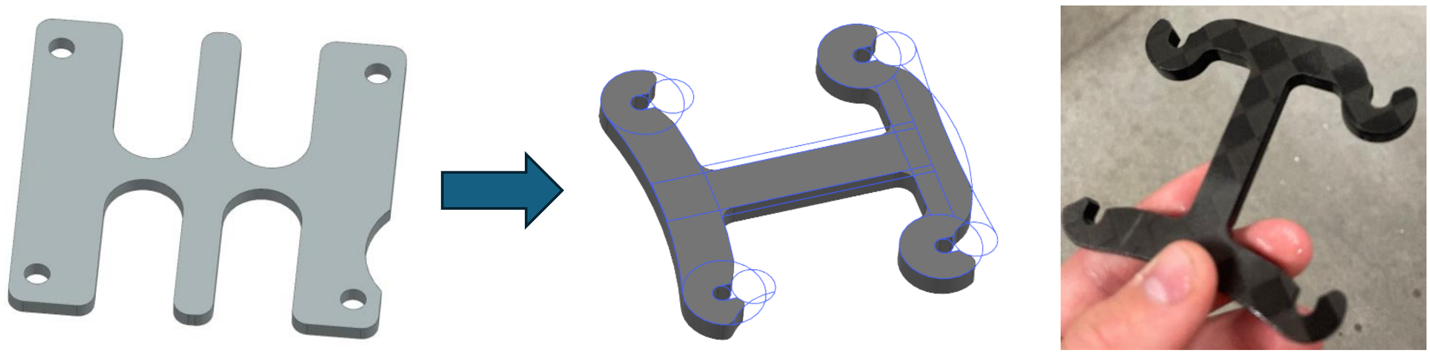
PCB Board Stack CAD:

Imported PCBs from Altium Designer into NX and created the board and spacer assembly using pattern constraints that load in a resource-efficient manner.

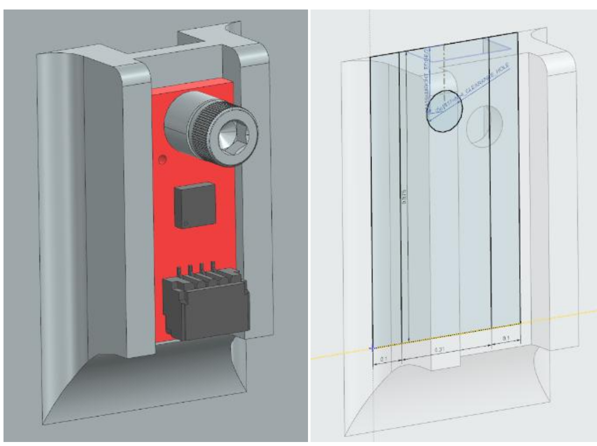


Carbon Fiber Battery Cover:

With the previous battery cover (shown on the left), the truss rods we added for reinforcement passed through all four holes and were secured by Loctite tuts. This meant that removing the battery cover to charge/replace the batteries was tedious. To address these issues, I designed a new cover (which was water-jetted out of carbon fiber fin stock for strength) with slots instead of holes, allowing the four nuts to be loosened rather than fully removed.



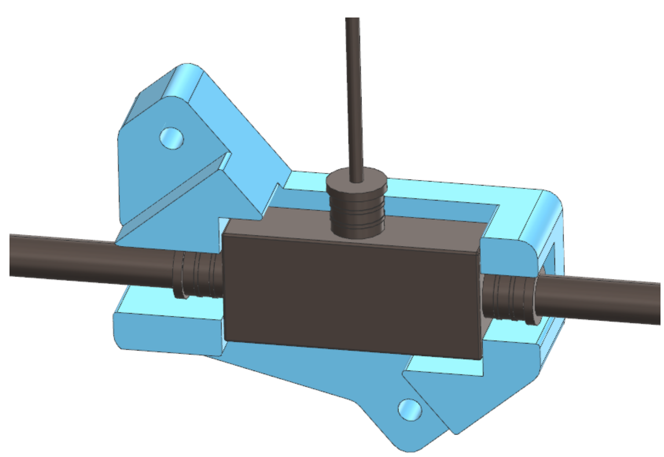
Magnetometer Mount:



To support the addition of an external magnetometer, I designed a brand-new mount. Unlike our other PCBs, the magnetometer only has one mounting hole, so I elected to constrain rotation using a set of rails on the side. Additionally, to reduce stress concentrations and ensure it was 3D-printable, I used fillets along the bottom and sides. Finally, to avoid electromagnetic interference, the mount is placed on the back side of the unit, far from anything else.

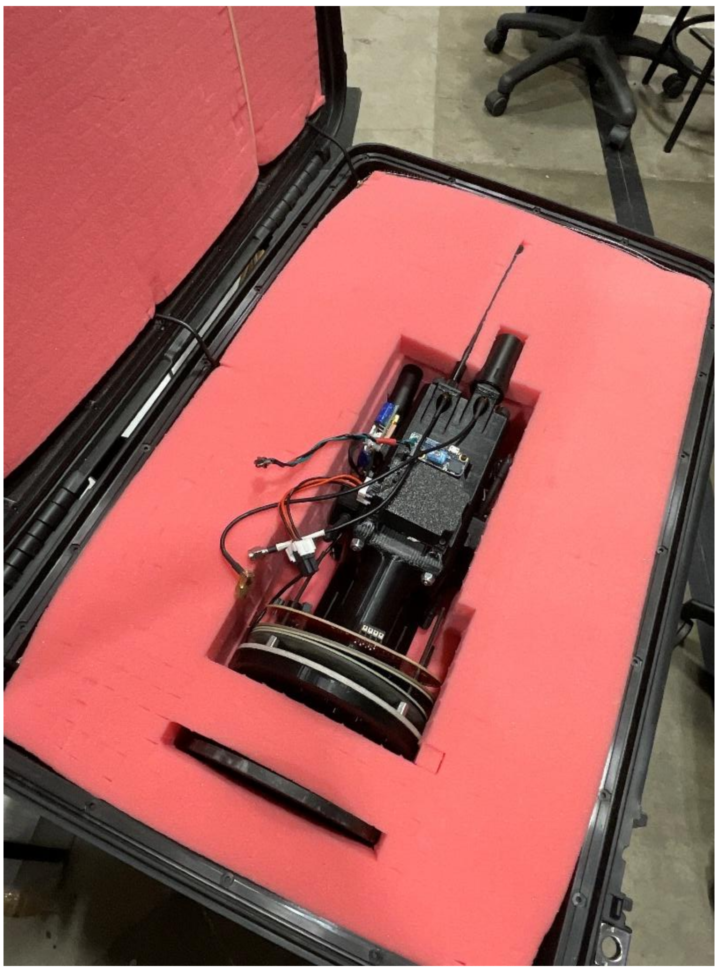
Angled Dipole Antenna Covers:

After realizing that the original 45° covers caused the antennas to protrude beyond the allowed diameter of the avionics unit, I designed a new mount from scratch that held them at 50°. This was difficult because the cover had to be reversible, allowing antennas to mount on opposite sides of the unit with no nosecone clipping and a valid location for all four screw hole mounts to go.



HAMSTER Cage (Protective Case for Avionics Unit)

I researched, designed, and built this case for our avionics unit (HAMSTER) after learning that it was transported to the launch site without any form of protection. Before ordering materials and constructing the case, I outlined the project requirements (durability, vibration cushioning, thermal insulation, and ESD protection), which led me to use a Seahorse waterproof hard-shell case with a carrying handle and wheels, pick-and-pull antistatic grid foam, and a steel mesh roll. The antistatic foam mitigates ESD risks, while the steel mesh serves as a Faraday cage to prevent external shocks and reduce electromagnetic radiation. Once my PDR was approved, I ordered the components and assembled them as shown. The mesh roll was cut into rectangular pieces that were soldered together to form a prism, then layers of foam were embedded in the center with cutouts to fit and cushion the avionics unit.

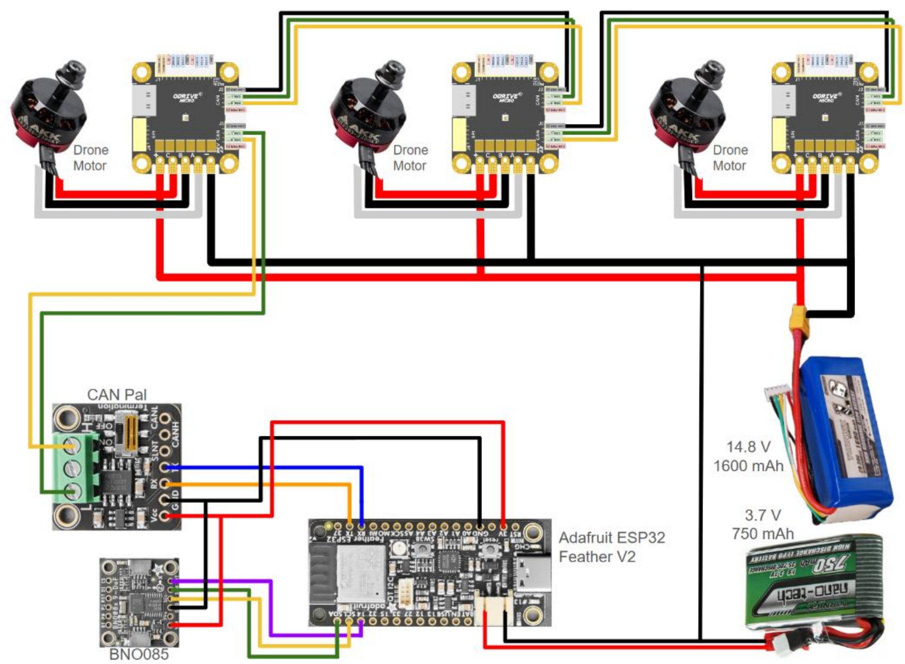


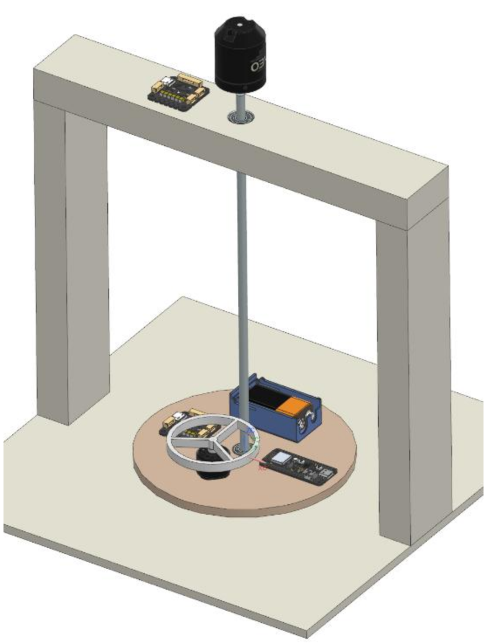
Payload Reaction Wheel GNC System

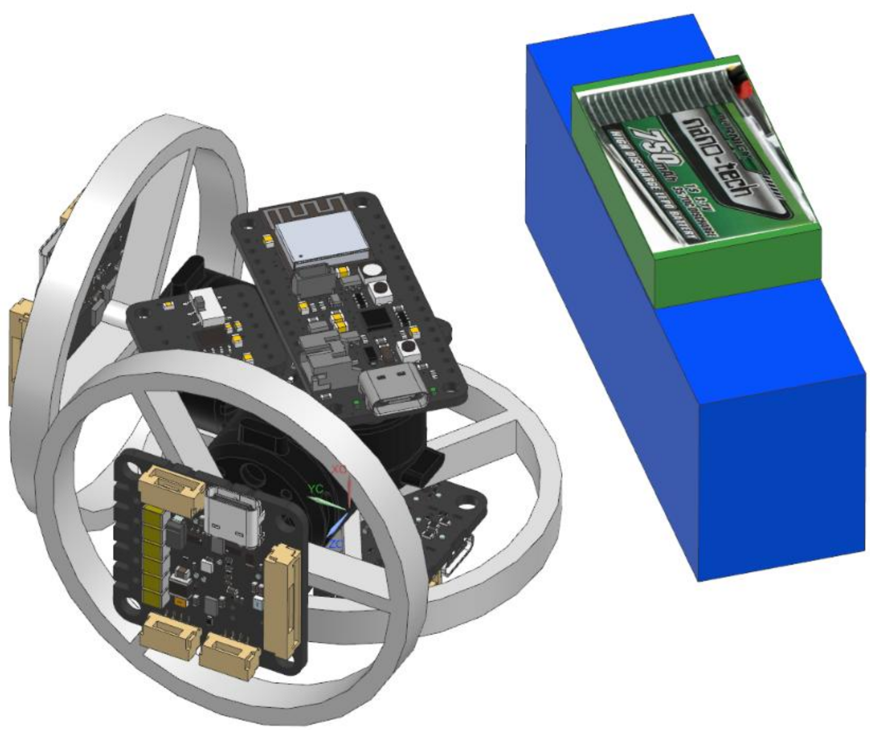
As Lead Avionics Engineer for a nine-member payload GNC team, I am developing a reaction-wheel based control system for the USC Rocket Propulsion's payload capsule – advancing lab's mission of creating a reliable student-led space program. As part of this responsibility, I did extensive research to define the avionics system architecture, ensuring all components integrate seamlessly. Through detailed trade studies, I identified an optimal configuration using high-kv drone motors, ODrive Micro motor controllers, an Adafruit ESP32 Feather V2 microcontroller, and a BNO085 IMU. I have also used Siemens NX to optimize CAD layouts, created wire harnesses, and written low-level communication software for system testing.

Notably, our team presented the project to the USC Viterbi Dean's Office, earning $12,315 to test on a Zero-G flight. Once finished, we plan to publish research on the feasibility of microgravity testing to validate and improve GNC simulations.

Shown here is the wiring diagram for the avionics system, proof-of-concept CAD for the reaction wheel configuration, and CAD for the single-axis test stand we are developing.



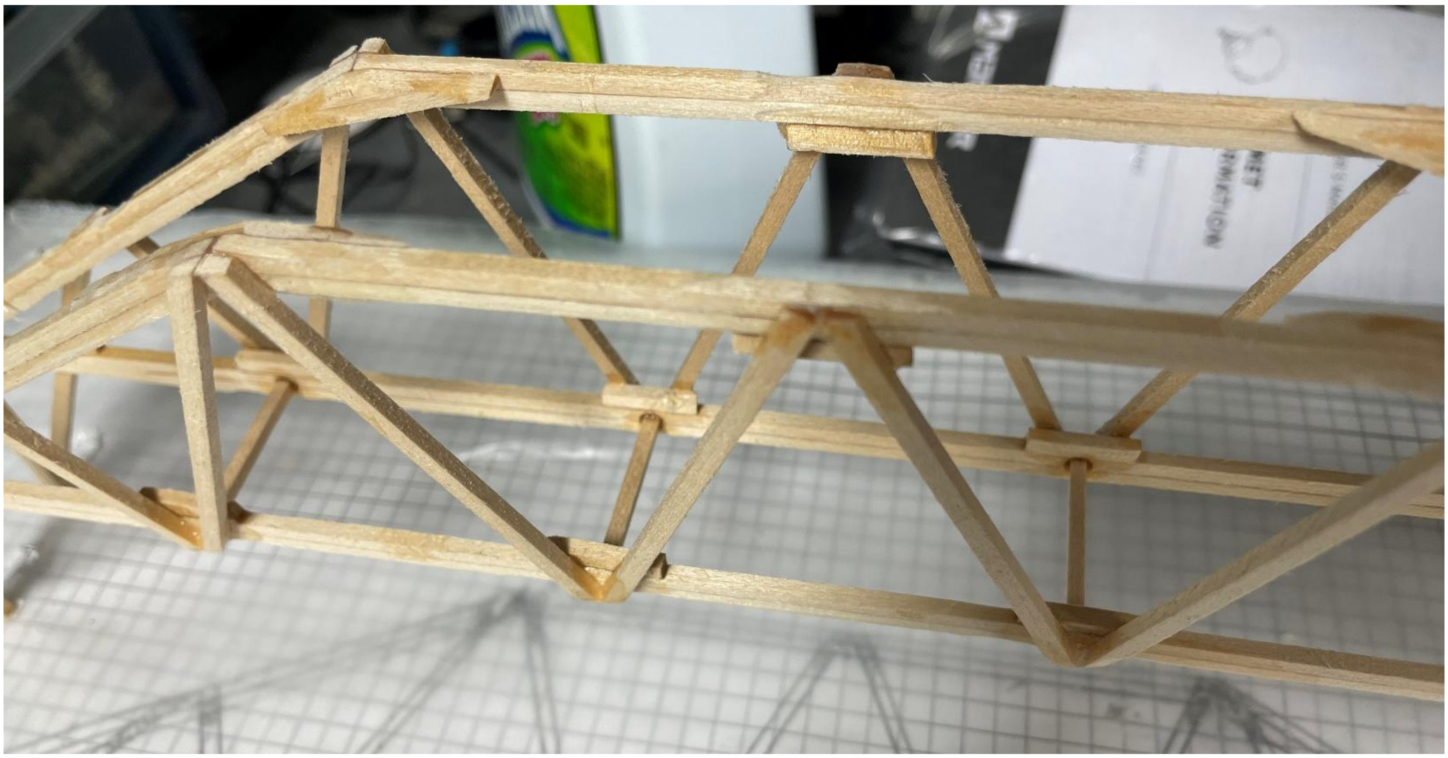


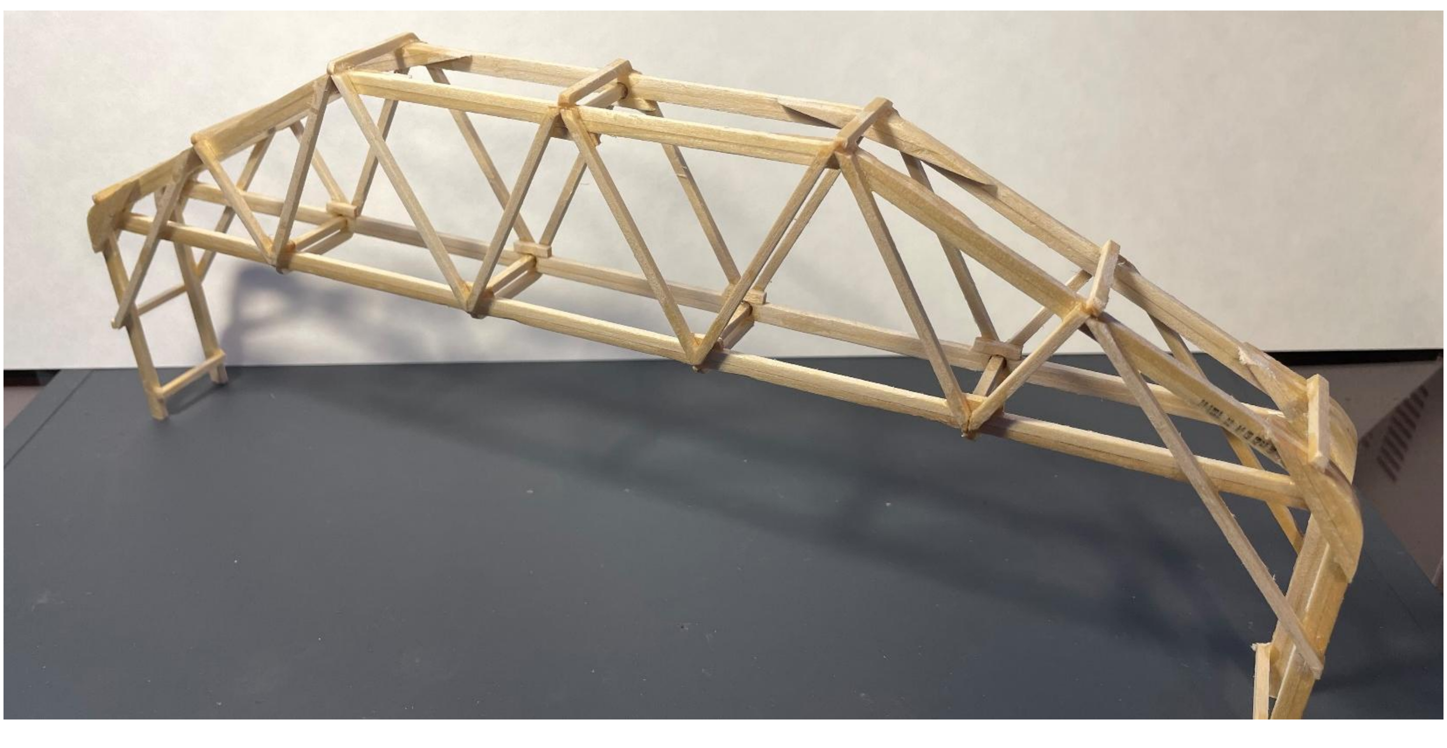


Additional Projects

45th International Bridge Building Contest

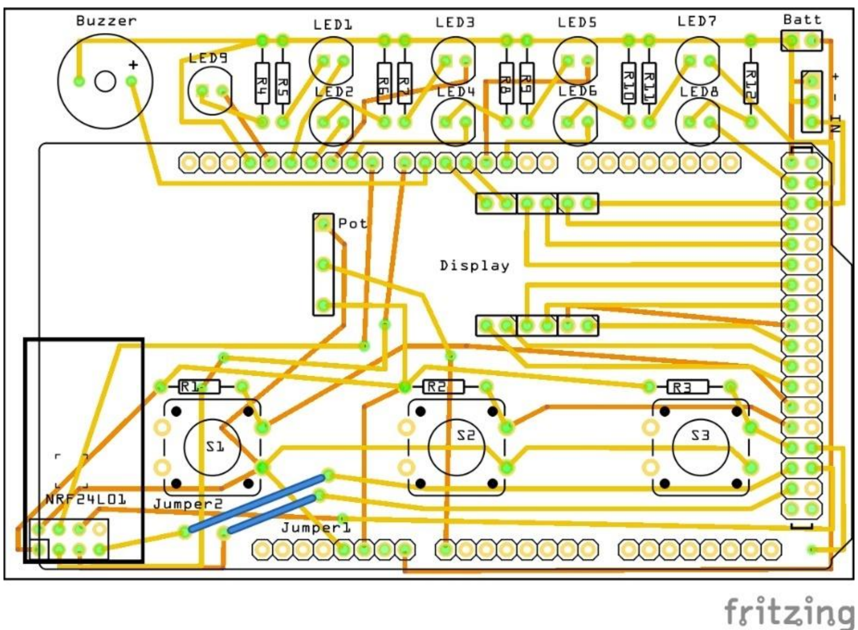
I created this bridge for the 45th International Bridge Building Contest in my junior year of high school, where I placed 4th after advancing from the school and regional competitions. The bridge was constructed from basswood sticks and cyanoacrylate glue, with a design that optimized efficiency (ratio of mass held to the mass of the bridge).

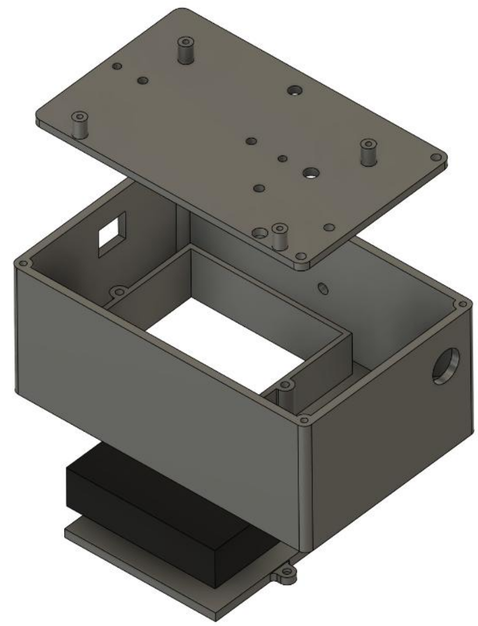


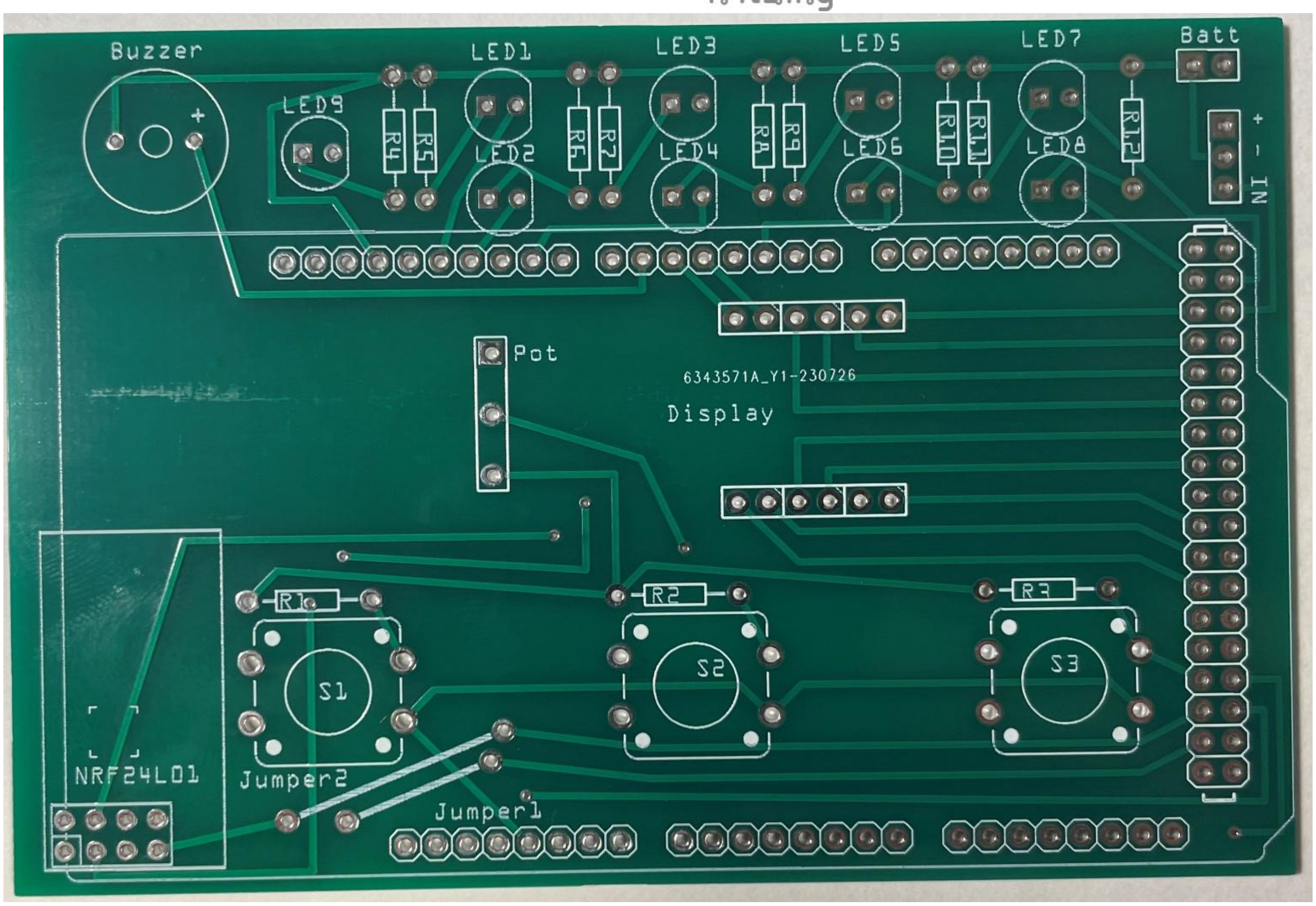


Model Rocket Countdown Timer / Flight Computer

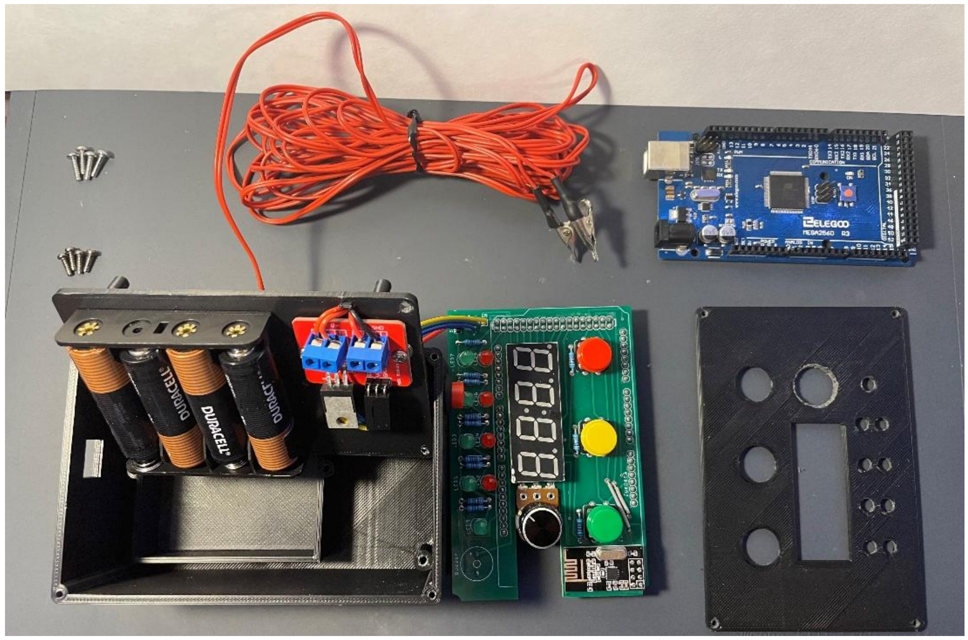
The following images show a PCB and schematic for a countdown timer intended to launch model rockets. Also shown is the CAD for a 3D-printed case to house the electronics. The PCB includes a 4-digit 7-segment display, indicator LEDs, a buzzer, a potentiometer, buttons, and an NRF24L01 radio module. It was designed to interface with an Arduino Mega.

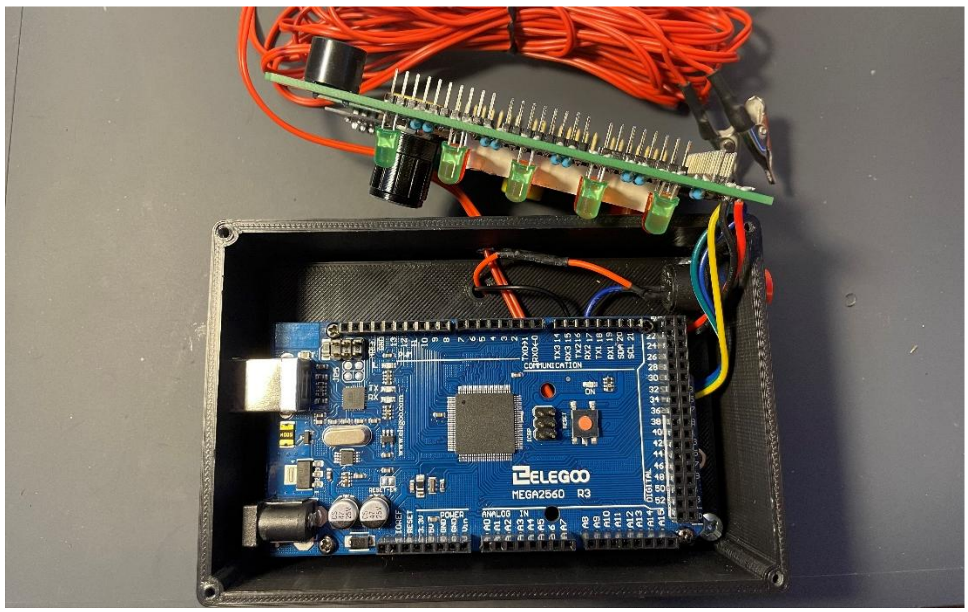


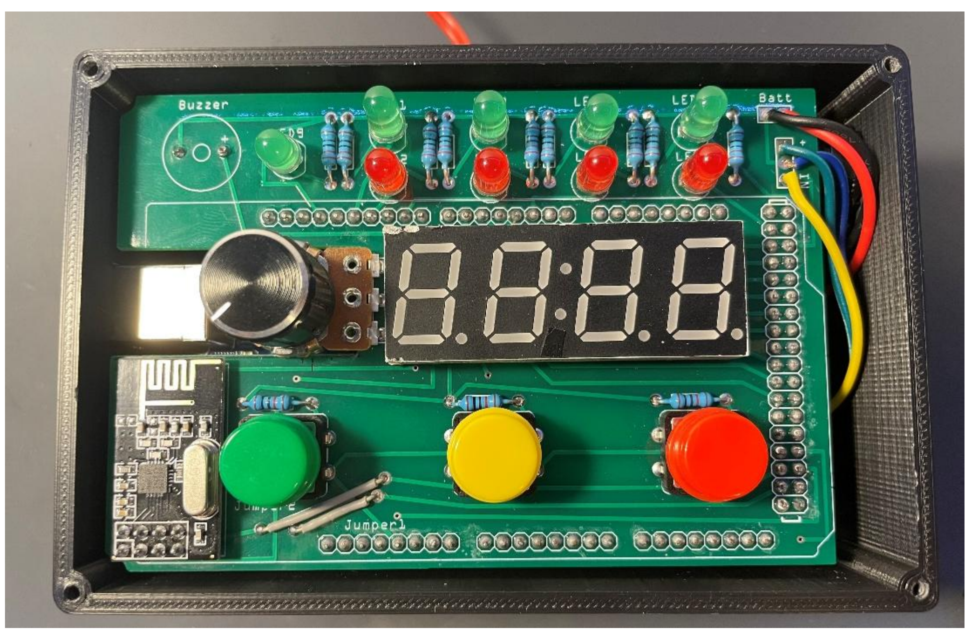




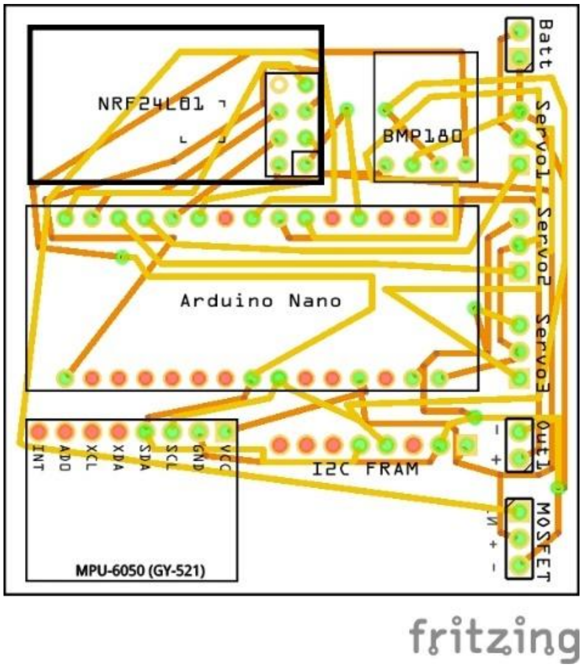
Shown here is the assembly process for the countdown timer. In addition to the components mounted on the PCB, there is an Arduino Mega, battery pack, and MOSFET driver.

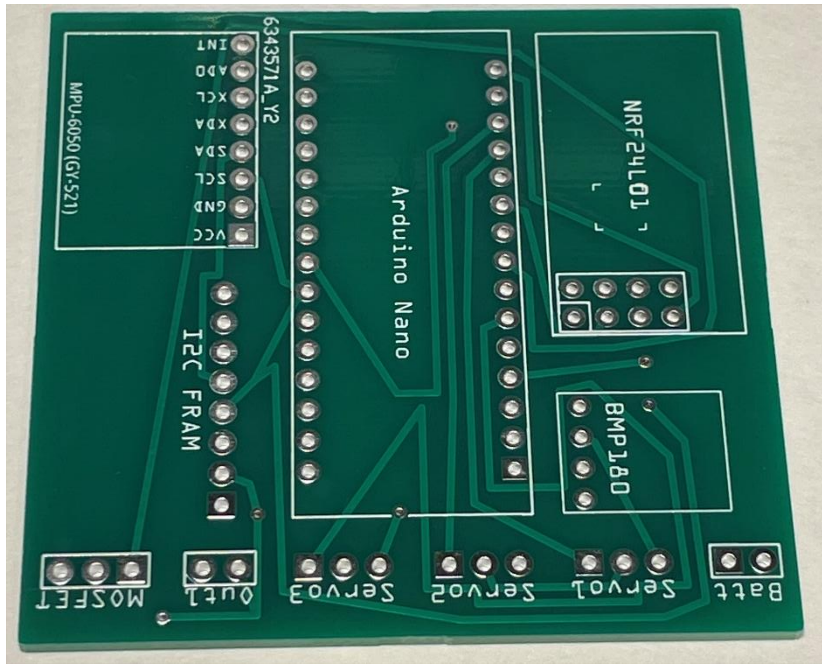


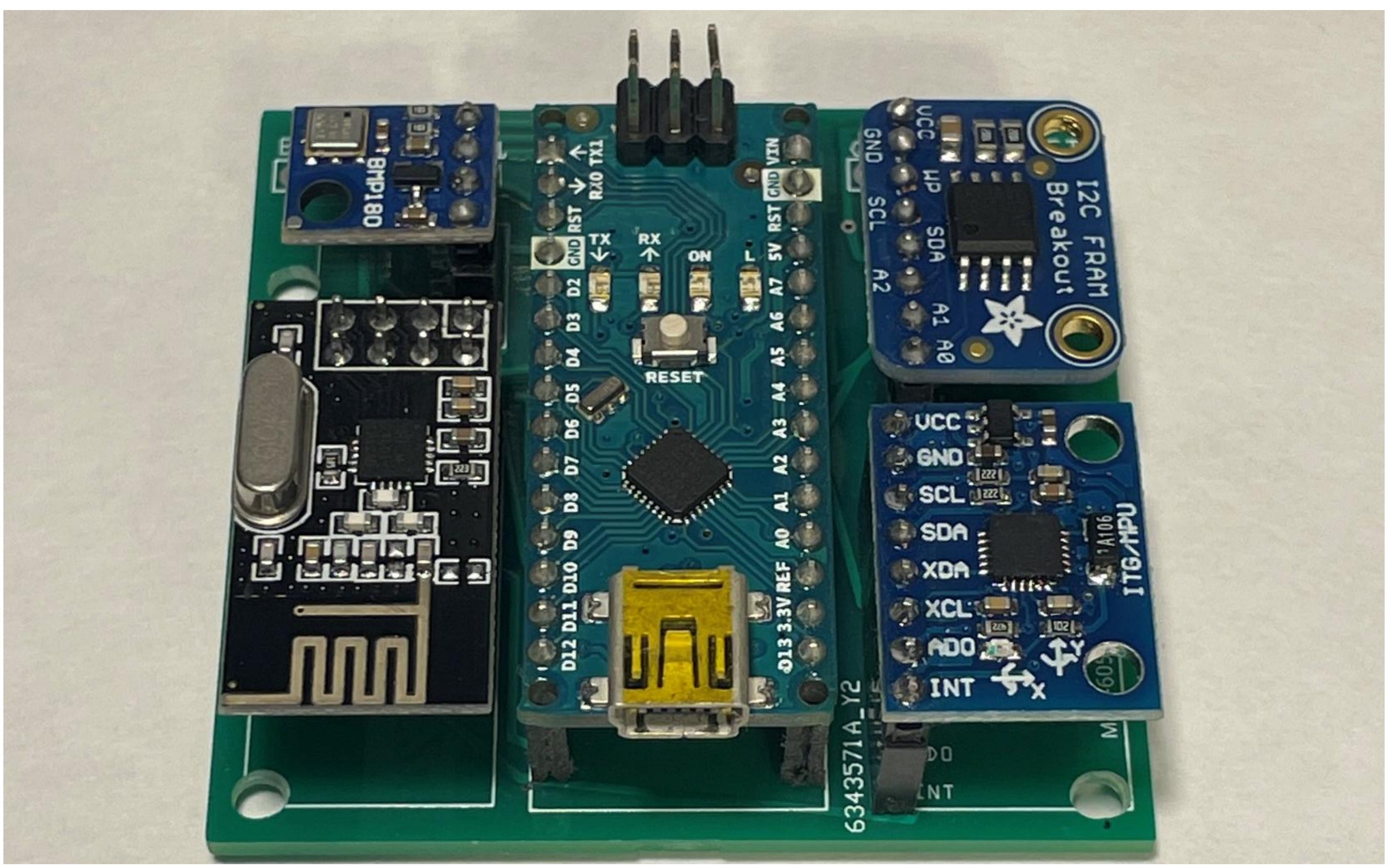




In conjunction with the countdown timer shown previously, I designed a flight computer for model rockets, whose PCB and schematic is shown here. The computer consisted of an Arduino Nano, a barometric pressure sensor, a 9-axis IMU, an FRAM storage module, and a NRF24L01 radio module for sending telemetry to the countdown timer.



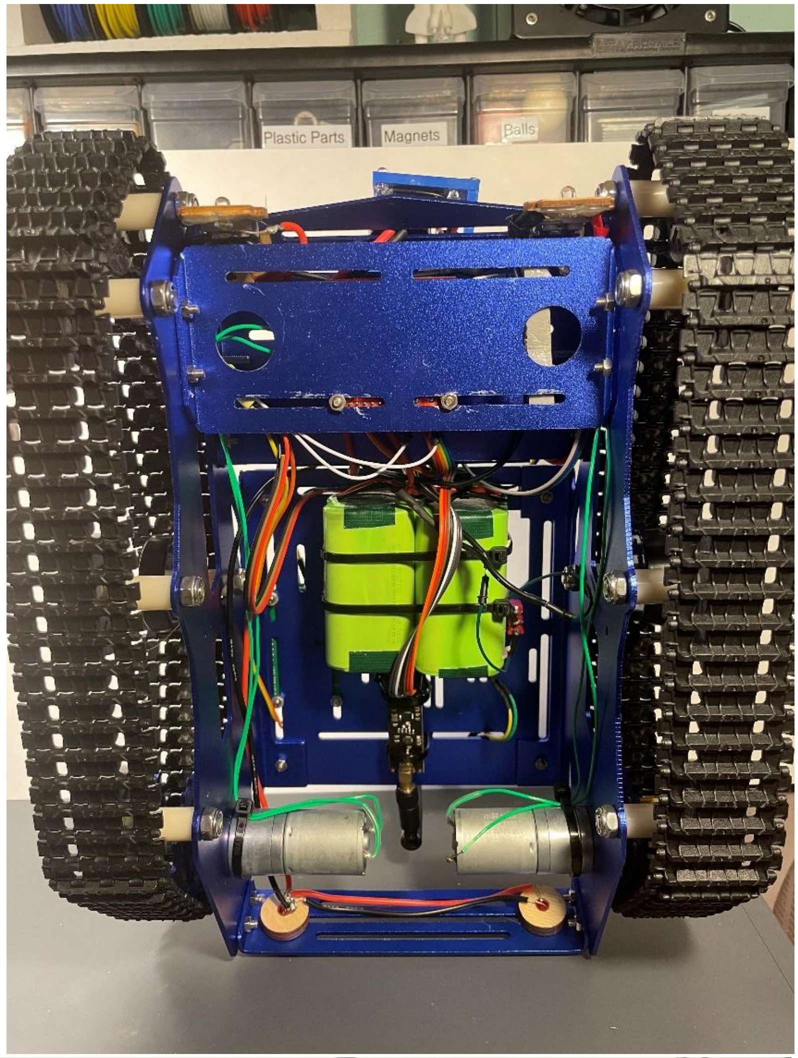


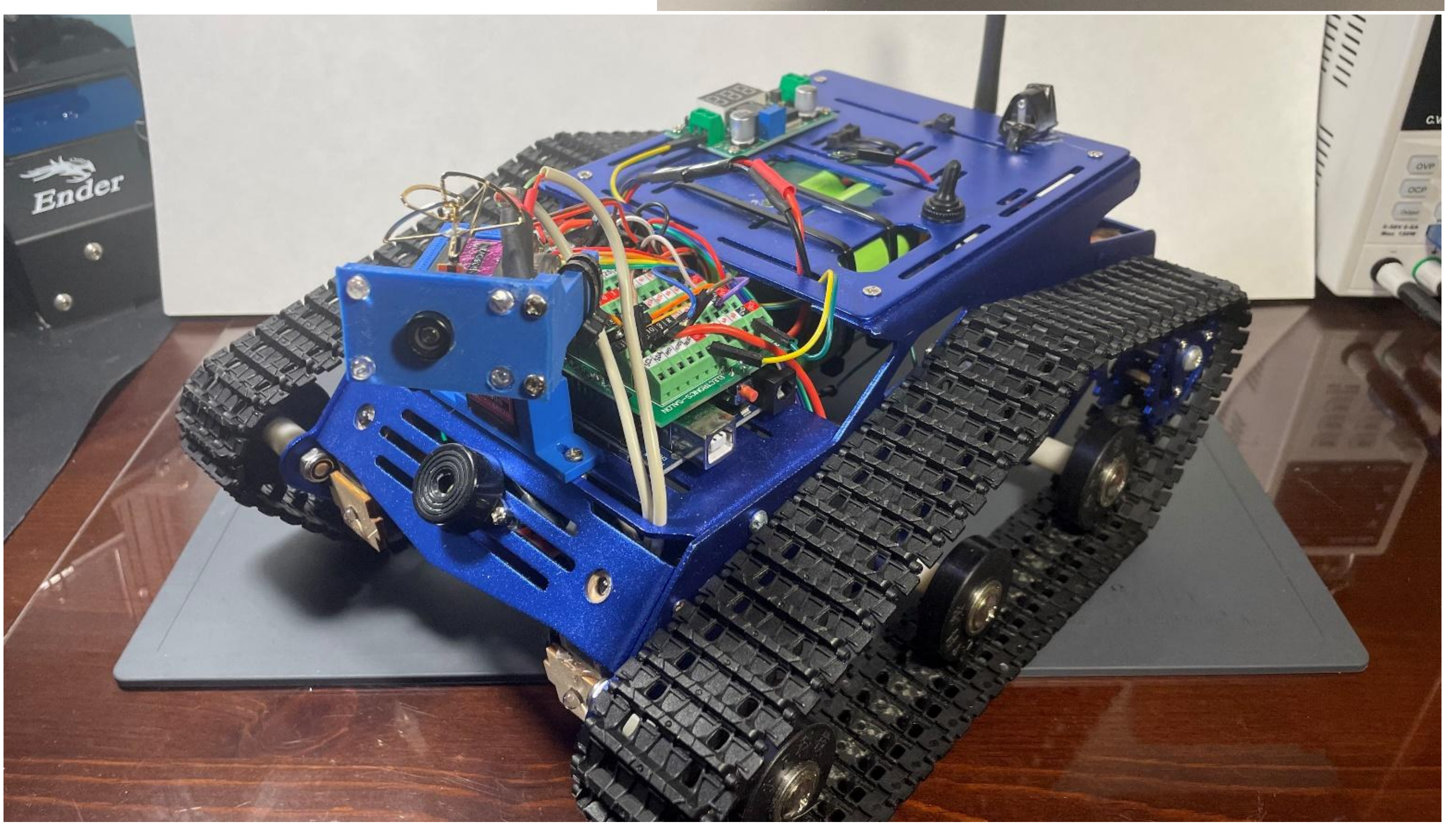


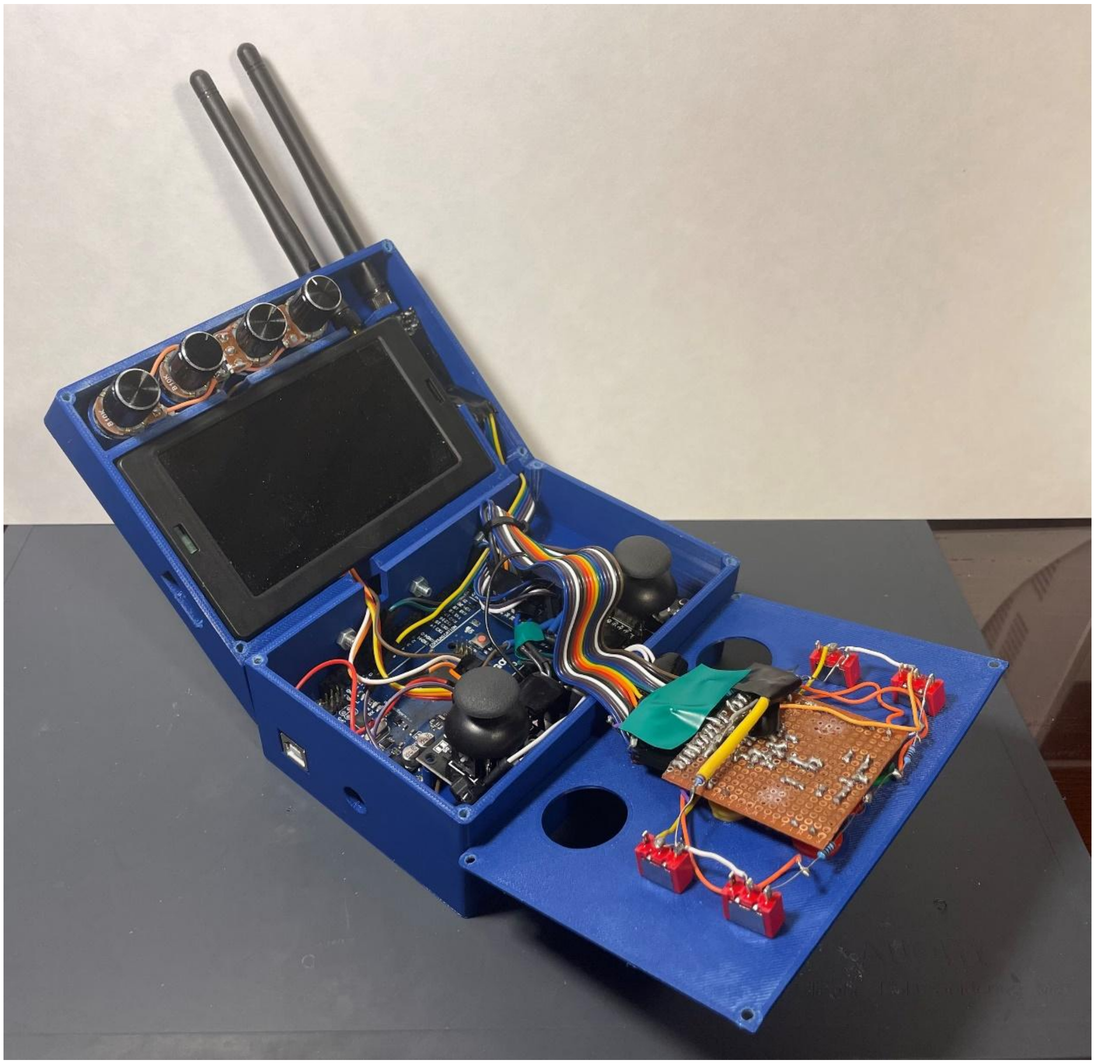
RC Rover and Remote

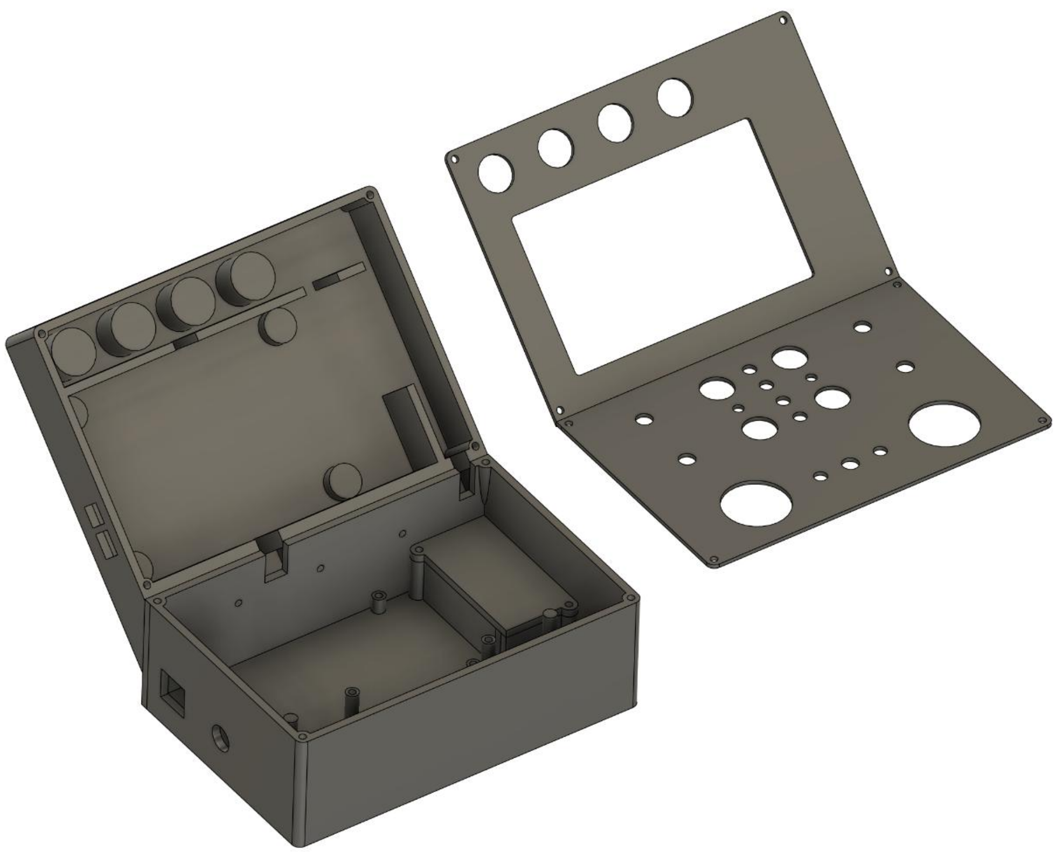
Shown here is an RC Rover I built using a commercial chassis with tank treads. The rover uses an Arduino Mega to control servo motors attached to a custom 3D-printed camera pan-tilt mechanism, a horn, L298N motor drivers, and a plethora of LEDs. An NRF24L01 module is also used, which communicates with the remote shown on the following page.

For the remote, I used a second Arduino Mega, which processes signals from joysticks, toggle switches, and buttons. Using another radio module, commands are then sent to the rover. An FPV drone screen is also used to display the camera view from the rover. All components are housed in a custom 3D-printed case, whose CAD is shown.





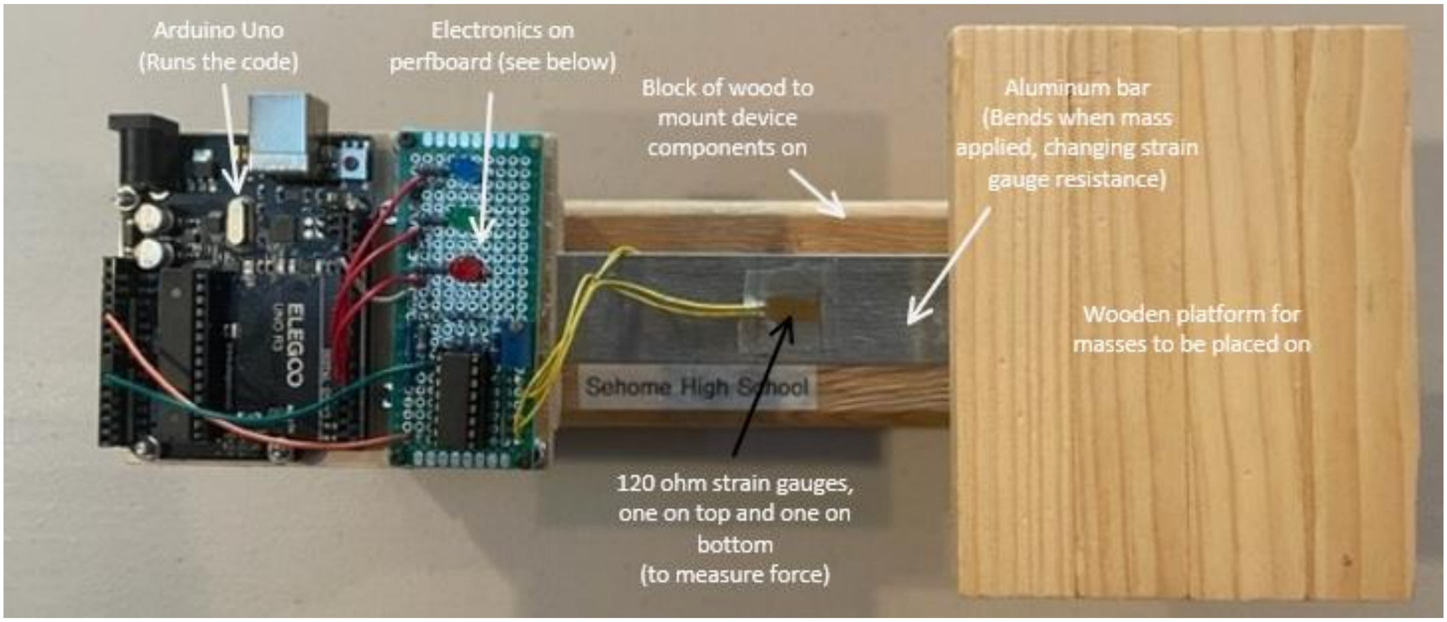


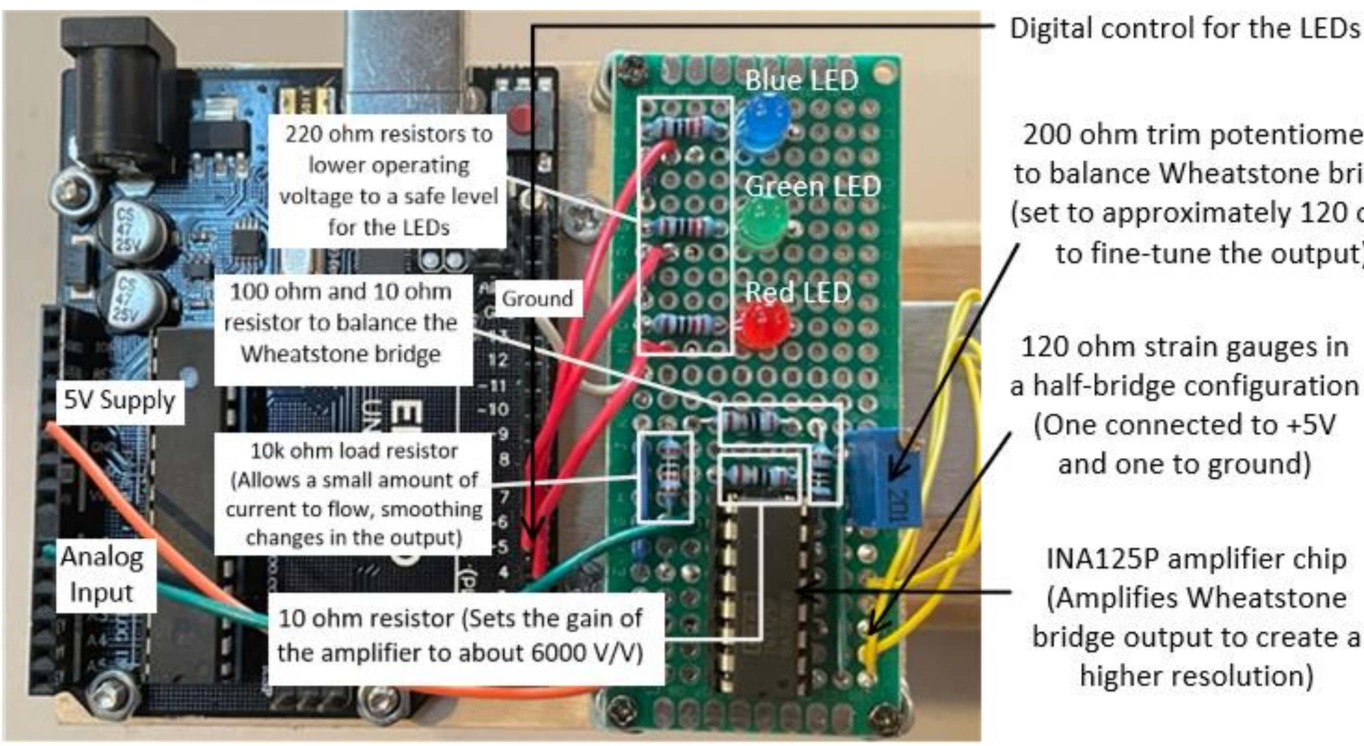


Detector Building Devices (Science Olympiad)

2023 Competition: The goal of this event was to create a device that could measure the mass of an object between 50 and 1000 grams and show the range within which the mass fell using three LEDs. The following description was modified from its original submission in the design log:

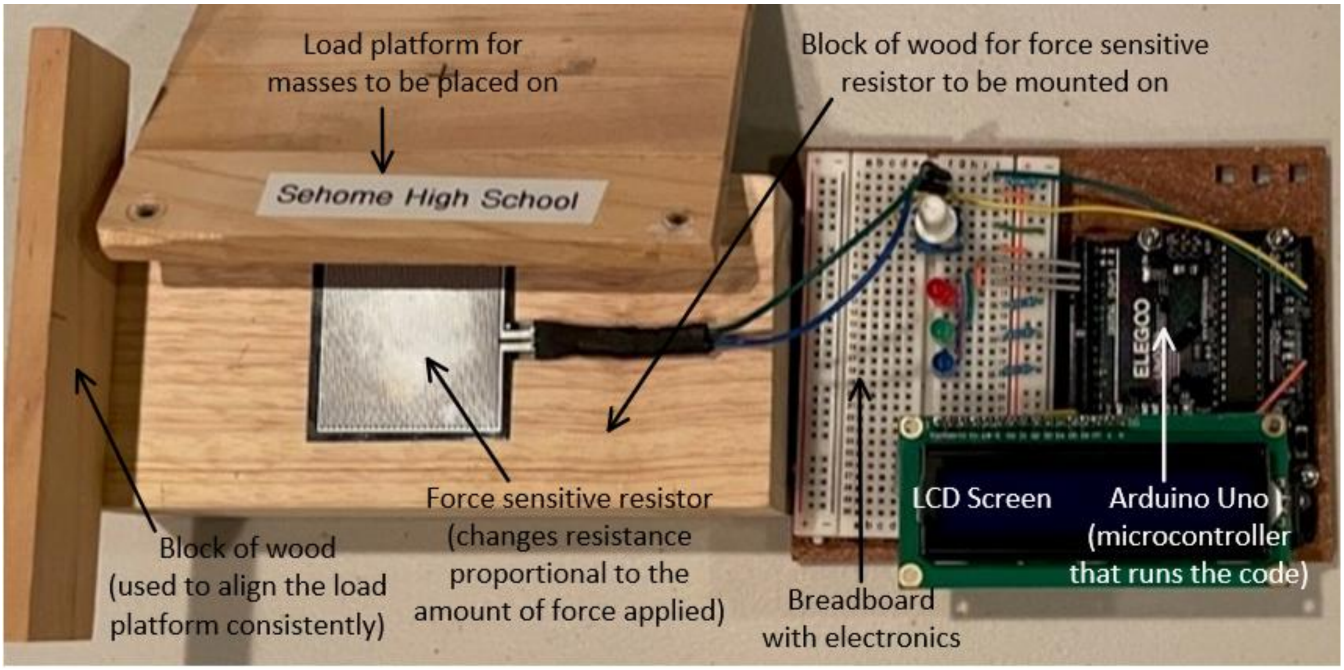
Version 1 Construction:

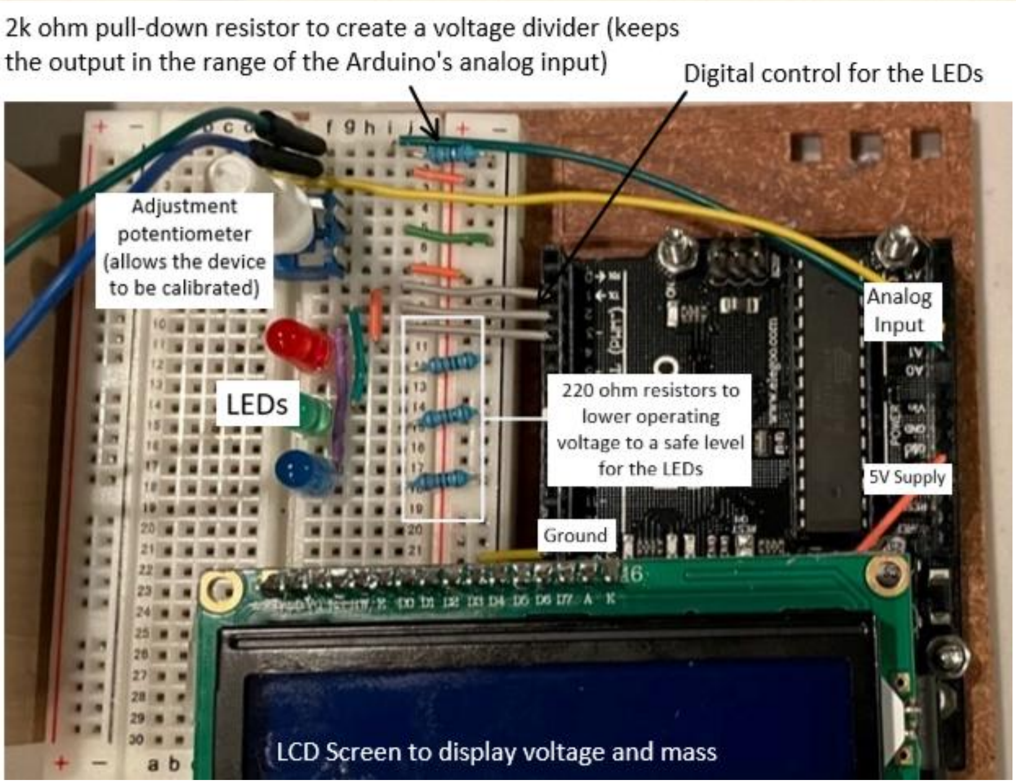




Unfortunately, the device was unable to be used because the strain gauges were too sensitive to factors such as temperature fluctuations and the changing flexibility of the metal over time, making reliable calibration of the device impossible.

Version 2 Construction:

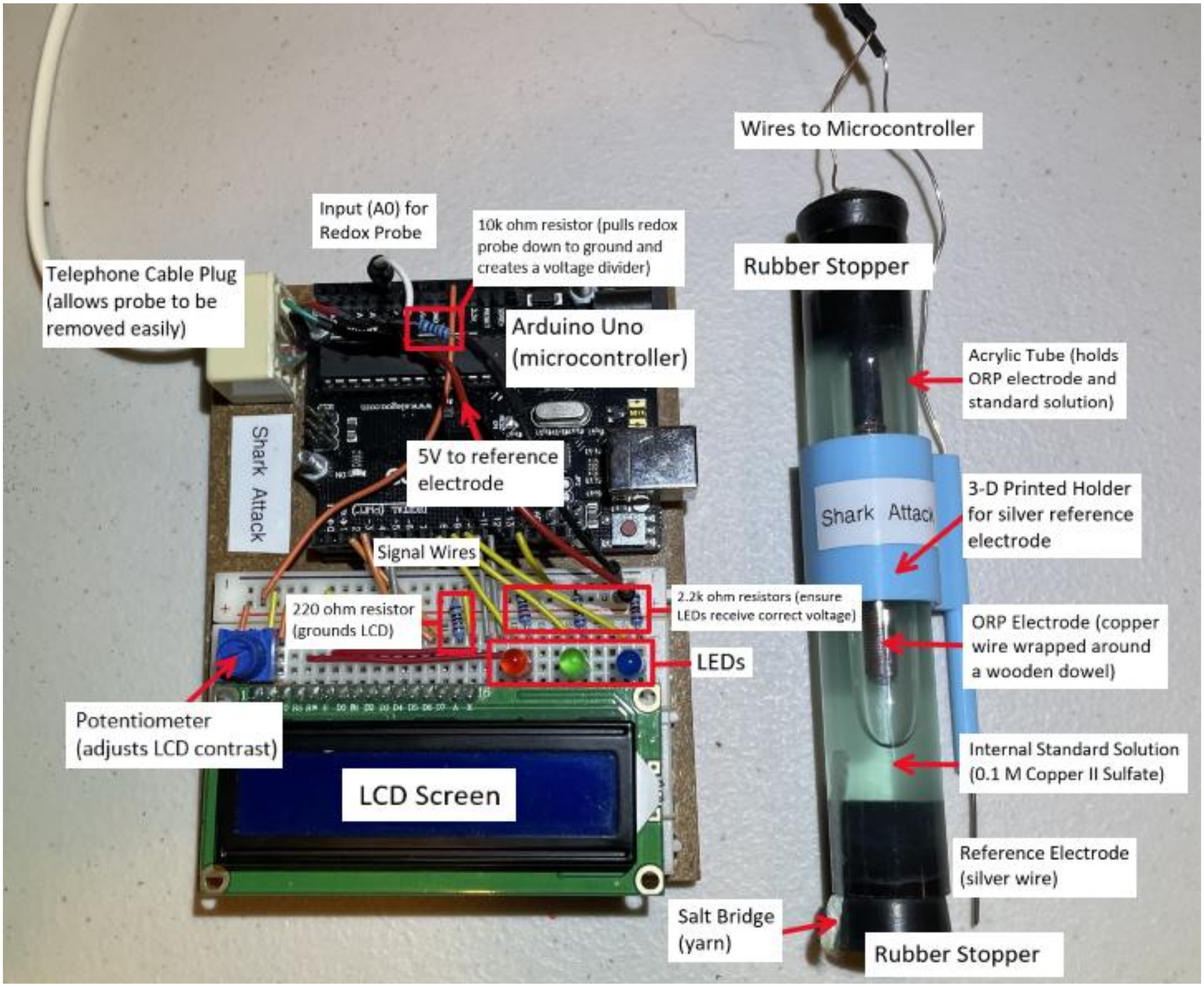




To address the shortcomings of Version 1, we opted for a simpler device that would be more reliable despite reduced accuracy. We chose to use a force-sensitive resistor (FSR) as the primary component, a choice that maximized simplicity and repeatability. When a mass is placed on the wooden load plate that sits on top of the FSR, it changes resistance proportional to the amount of force applied, and the Arduino Uno measures a corresponding voltage value from 0 to 5V. A potentiometer is used to adjust the zero value of the device to account for variability such as the placement of the load plate.

2024 Competition: The goal of this event was to build a device that could measure the concentration of salt in a cup of water and display the range where it fell using three LEDs. The following description was modified from its original submission in the design log:

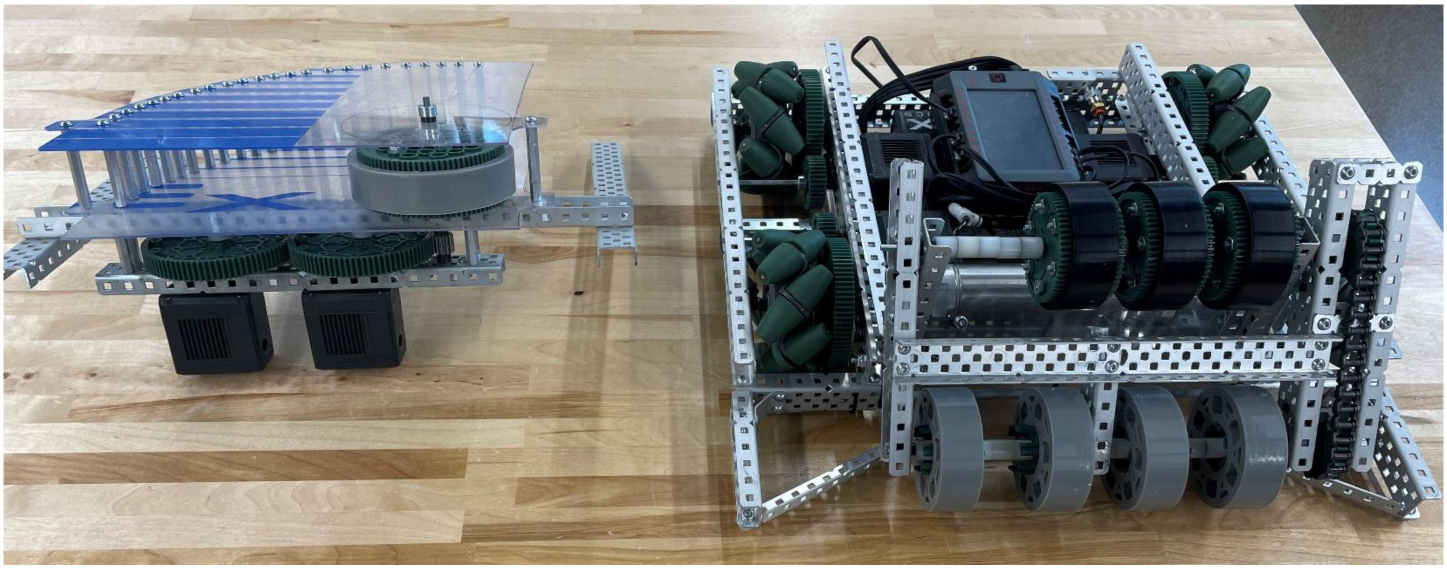
Device Construction:

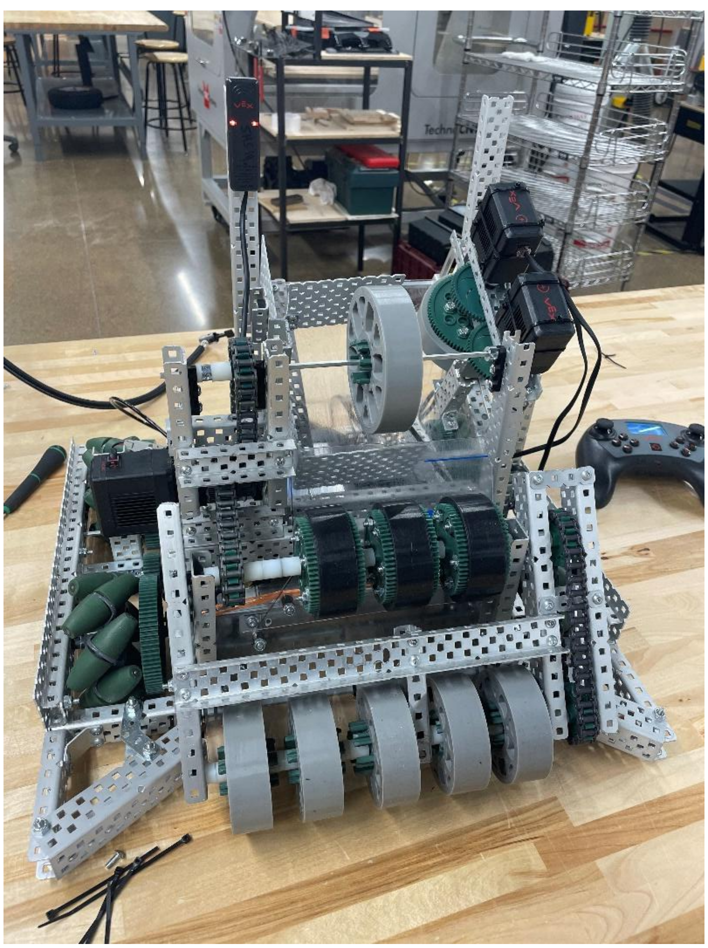


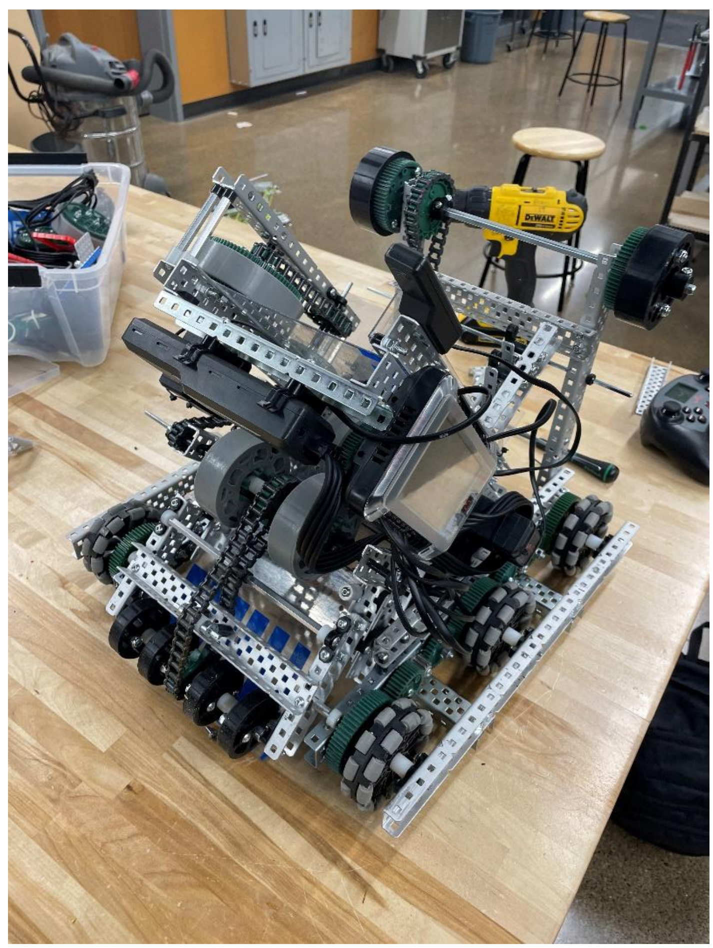
The redox probe is constructed from an acrylic tube with rubber stoppers on each end. At the measuring end of the probe, a piece of yarn acts as a salt bridge between the internal standard solution (0.1 M Copper II Sulfate) and the solution to be measured. A 3D-printed holder for the reference electrode (silver wire) is friction-fitted to the tube. At the opposing end, the copper ORP electrode extends through the center of the rubber stopper. The wires from both electrodes connect to the microcontroller through a telephone wire. The reference electrode is supplied with 5 volts of power while the ORP electrode is connected to the Arduino Uno analog input and a grounded pull-down resistor, allowing calculation of the salt concentration by measuring the voltage drop.

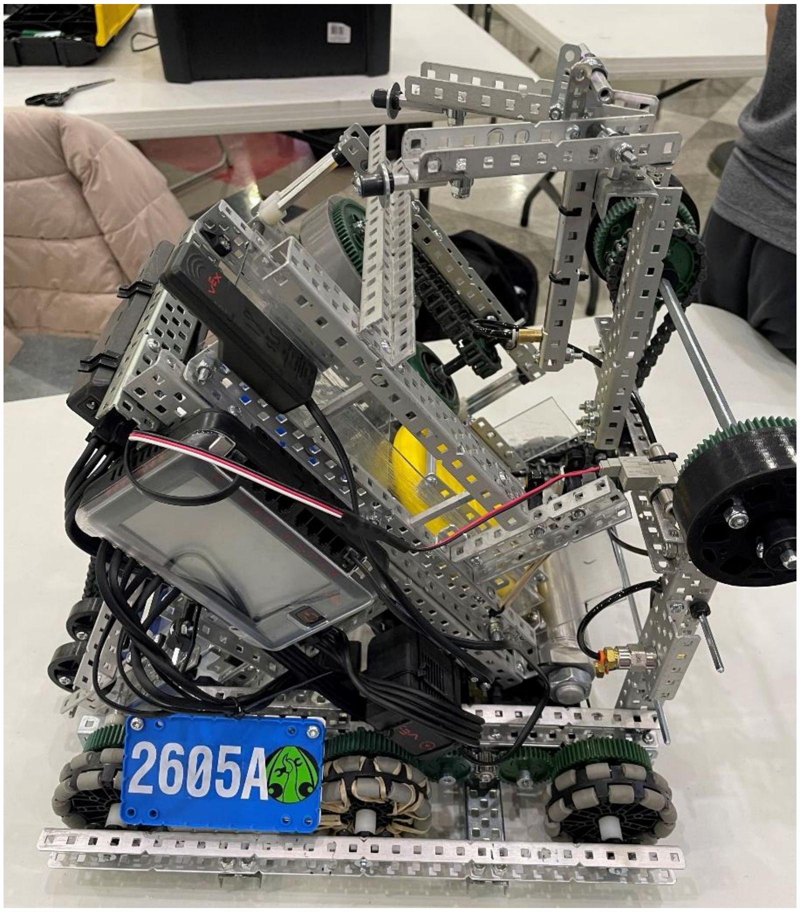
VEX Robotics Competition

In my high school robotics class, I competed with a partner in the VEX Spin-Up game. The progression of our robot can be seen in the following images. Our final design used the VEX V5 electronics system (programmed in Python) to control a 6-wheel omni wheel drive, a flywheel, a roller intake mechanism, a pneumatic launch-angle adjuster, and a pneumatic string launcher. During the season, we won the Whatcom VEX League Skills Award and competed at state.








2605A

Space Debris Collection System (Proof of Concept)

For an introductory engineering course at USC, my team tasked with designing a 3D-printed prototype for a project of our choice. We settled on a space debris collection system and 3D-printed a spring-loaded prototype. The design consists of 3 sliding modules, which spring apart upon the release of a latch mechanism to expand a net, which would be used for capturing space debris. Shown below is the CAD and the design in both the closed and open configurations.