Engineering Portfolio

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Coursework Projects

My coursework projects integrate control theory, dynamics, and vibration analysis to model, design, and optimize real-world electrical and mechanical systems. Through these projects, I’ve developed experience in applying feedback control, system identification, and simulation-based design to achieve stable and efficient system behavior.

The Drone Altitude Controller project allowed me to implement and tune PID control loops, address nonlinear effects such as actuator saturation and integrator windup, and refine performance using frequency-domain methods. Projects in dynamic system optimization and vibration isolation further strengthened my understanding of how physical parameters and control strategies interact to govern system response.

Together, these projects demonstrate a strong foundation in system optimization and the ability to connect analytical models with experimental performance.

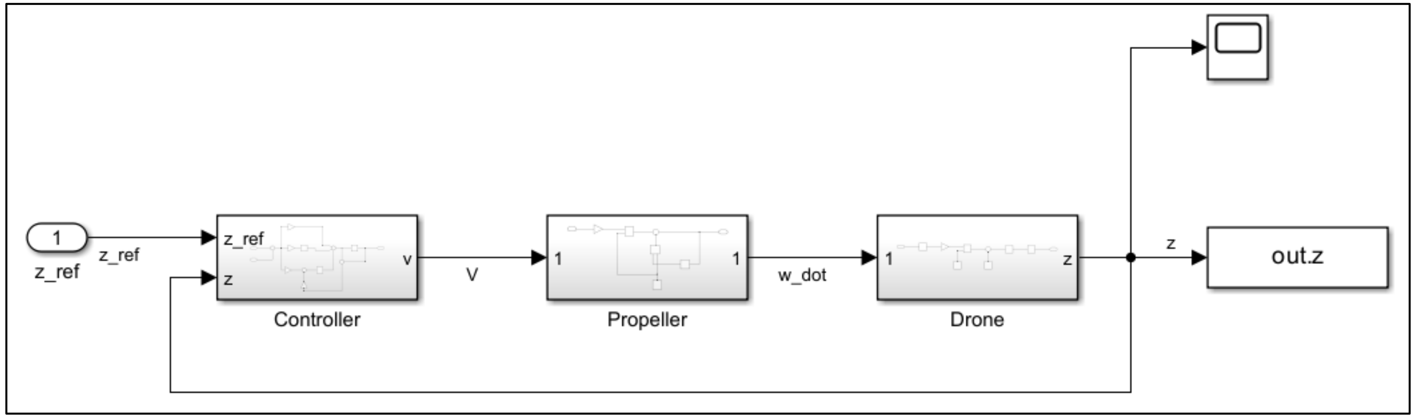
Project: Drone Altitude Controller

This project represents the initial stage of a larger drone control simulation developed for my Control Systems Engineering course. The long-term goal of the project is to create a full simulation of a quadcopter capable of tracking a reference position in three-dimensional space.

The first milestone focuses on the altitude (z-axis) control subsystem. The model includes a simplified physical representation of the drone's mass, a propeller generating thrust, and both a reference altitude signal (a sinusoidal trajectory) and an actual altitude obtained by double integration of the system's acceleration output. This foundation serves as the testbed for developing and refining the control architecture before expanding to full 3D motion control.

Controller Design and Stability

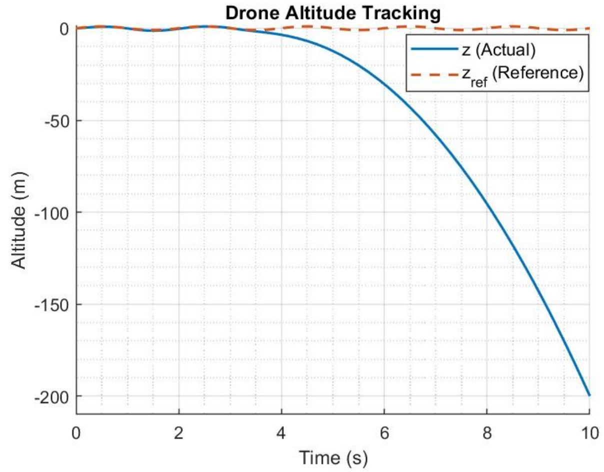
- Altitude control loop implemented using a PID controller that regulates propeller thrust to achieve a desired altitude
- Nonlinearity due to propeller voltage saturation affects stability
- I will continue to refine the PID gains using control analysis techniques such as root locus design and MATLAB's Control System Toolbox for a more robust controller configuration



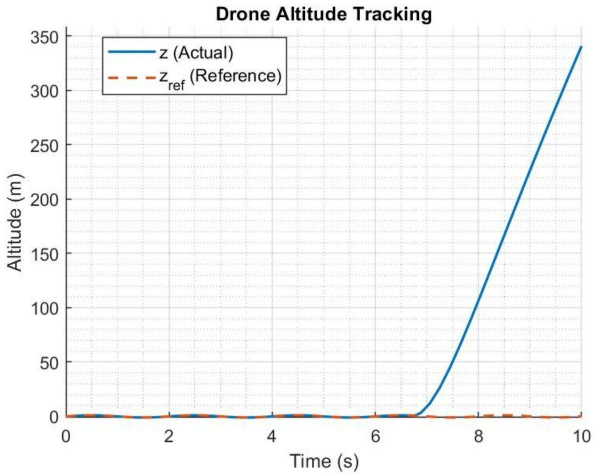
Tracking & Integration Windup

- Case 1 shows a drone whose propellers are too weak and cannot recover from a slight disturbance like one caused by windup
- Case 2 shows adequately spec'd propellers still in the windup case. Once the integration term reaches a threshold, the altitude asymptotically rises in this case
- I implemented an anti-windup feedback loop to limit the integrator output when the actuator saturates, preventing accumulation of error

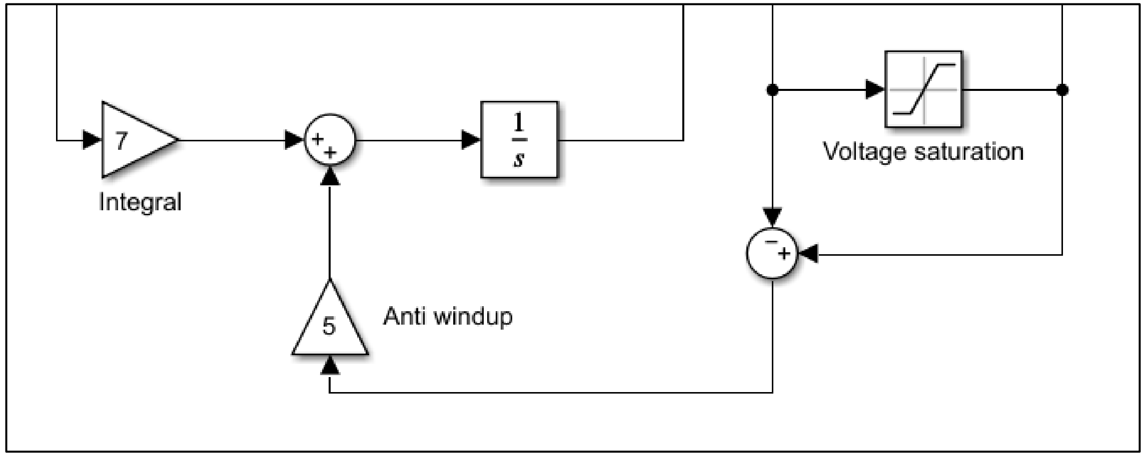
Case 1



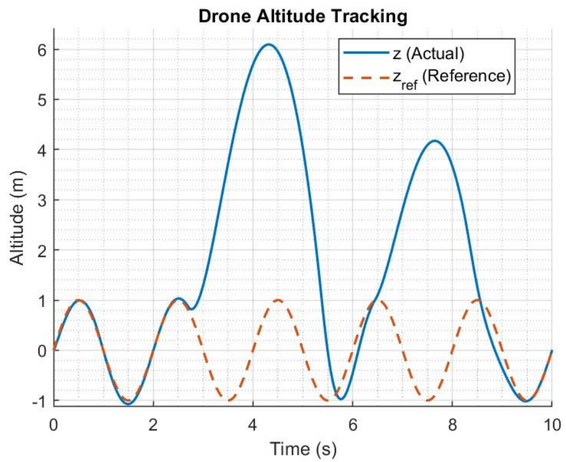
Case 2



Anti-Windup Feedback Loop

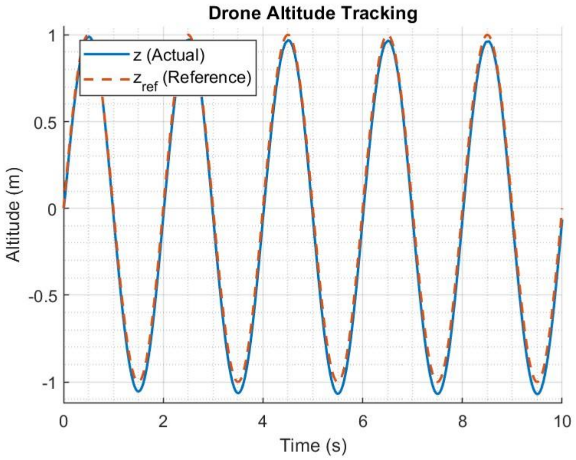


Case 3



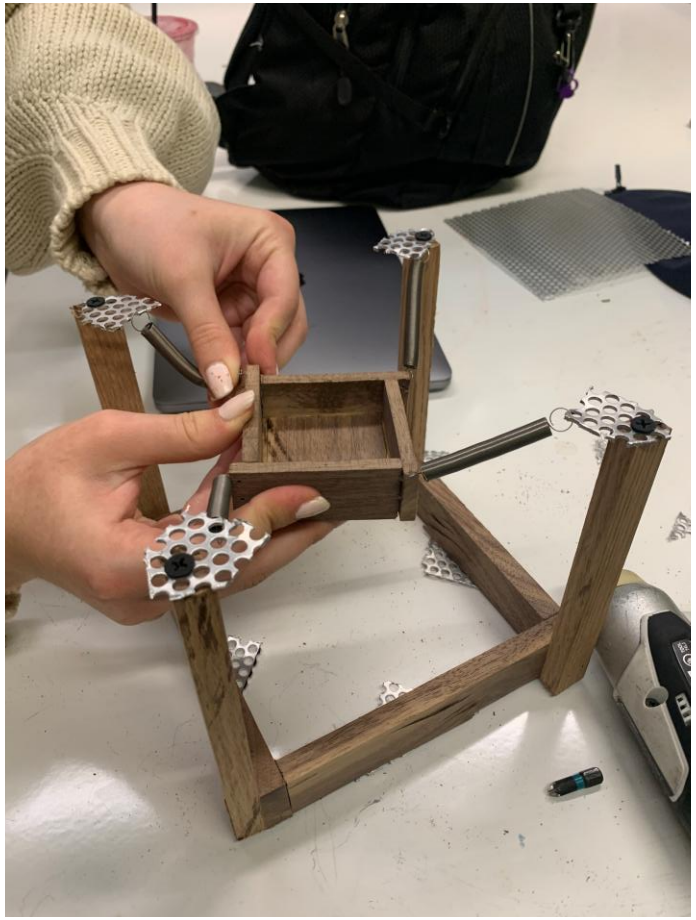
- I then tuned its gain so that it does not overpower other constants (Case 3)
- The last plot shows the response after tuning. It displays a responsive system and low steady-state error. Error at the extrema of the reference wave is acceptable by the project requirements

High-Fidelity Tracking



Project: Vibration Isolation System

- For a Dynamics and Vibrations project, our team designed and tested a spring-mass vibration system to minimize transmission of shake-table vibrations to a suspended platform
- Used analytical modeling to derive the system's natural frequency (2.1 Hz) and transmissibility (0.0022 at 45 Hz) under sinusoidal excitation
- Experimental natural frequency 2.2Hz, and higher transmissibility due to damping

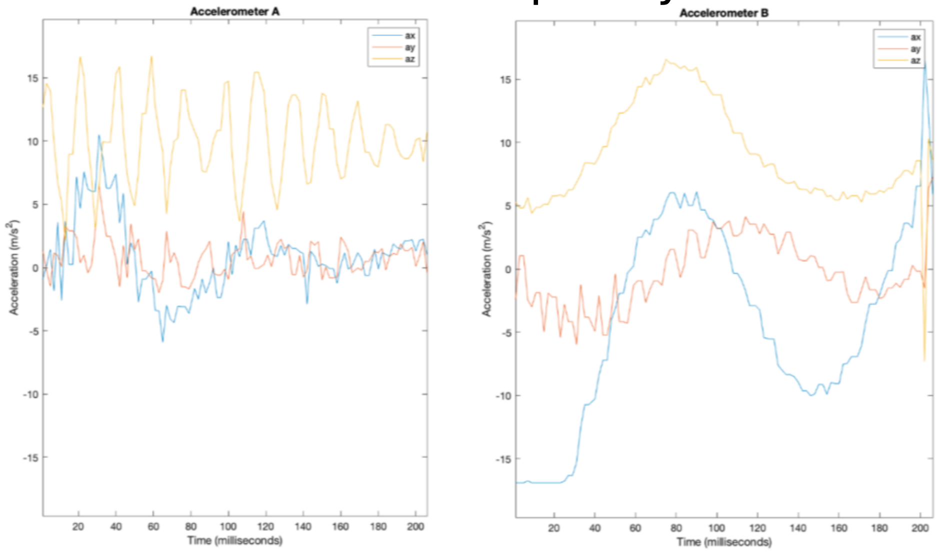


Accelerometer A: shake-table

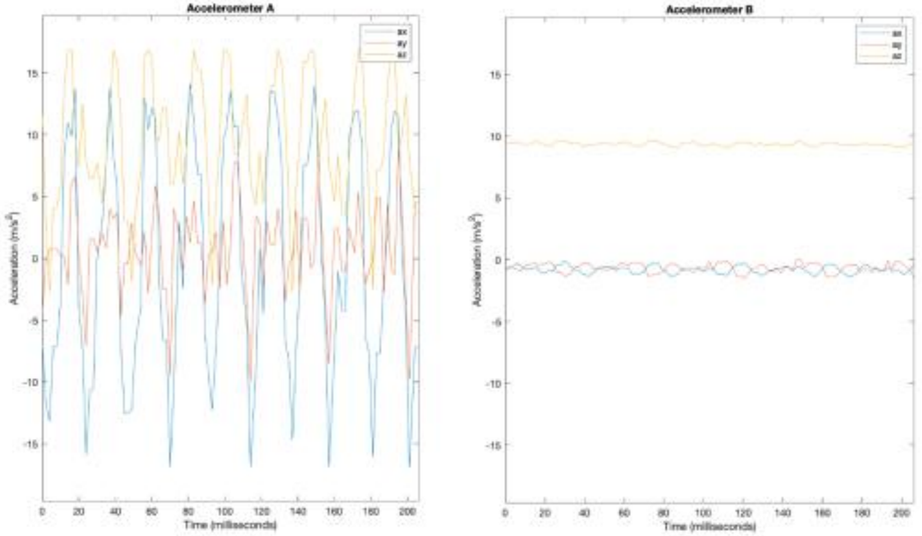
Accelerometer B: platform

- At 2.2 Hz, system resonance caused high amplitude oscillations to throw the mass off the platform
- This then lowered the mass of the platform, raising the natural frequency
- At higher frequencies including 45 Hz, the vibrations were almost completely isolated to the shake-table

Shake-Table Frequency 2.2Hz



Shake-Table Frequency 45Hz

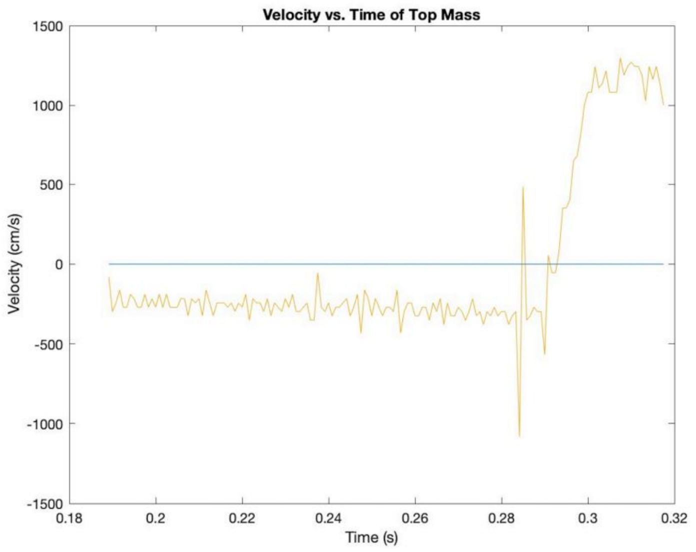


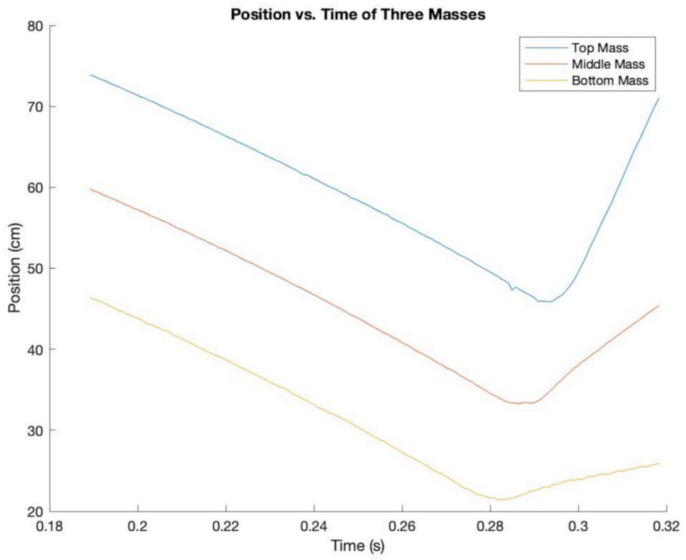
Project: Mass Launcher

- For a Dynamics and Vibrations, my group optimized a three-mass, three-spring projectile launcher for launch velocity
- Used Hooke's Law and Newton's 2nd Law as well as MATLAB's fmincon optimization tool to determine the optimal set of masses and spring constants

Mass Launcher

- Used cameras to track and plot mass positions, then differentiated for velocity
- Experimental launch velocity of 40.7 ft/s closely matched theoretical 43.3 ft/s, validating the analytical model



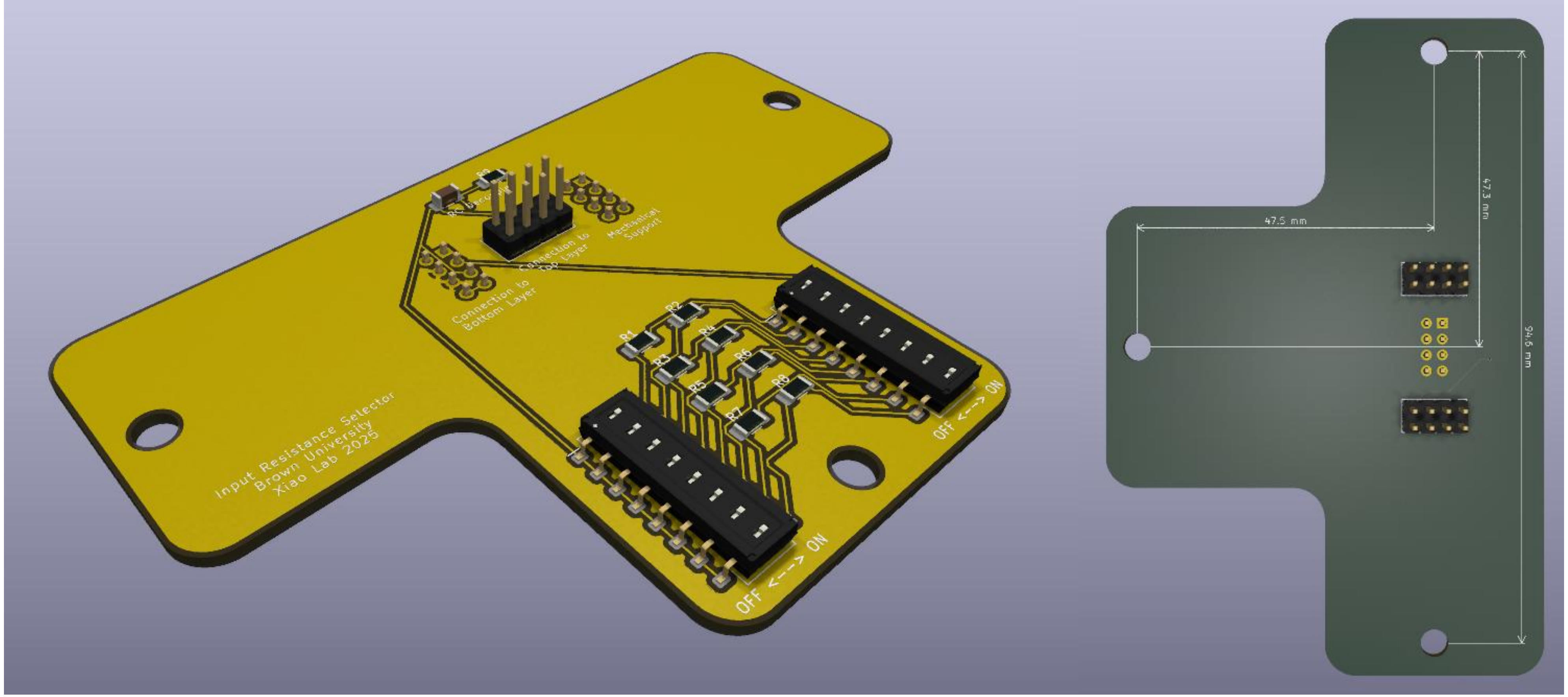


Lab Projects

As an undergraduate research assistant in the Nanoscale Physics and Quantum Devices Lab at Brown University, I work on projects aimed at developing highly sensitive magnetic field detectors capable of measuring fields in the picotesla range with minimal noise. A key focus of the group is understanding the causes of and mitigating electrical noise in magnetic tunnel junction (MTJ) devices.

My work specifically centers on characterizing and reducing intrinsic noise in MTJ arrays. Working closely with the member of the team responsible for running measurements in the Faraday cage, I help design, test, and analyze systems that sample intrinsic electrical noise. These measurements are performed by connecting the MTJ array to a DC voltage source and data acquisition system (DAQ) without applying an external magnetic field, then analyzing the resulting noise spectra in the frequency domain.

Project: Input Resistance Selector Circuit



Purpose

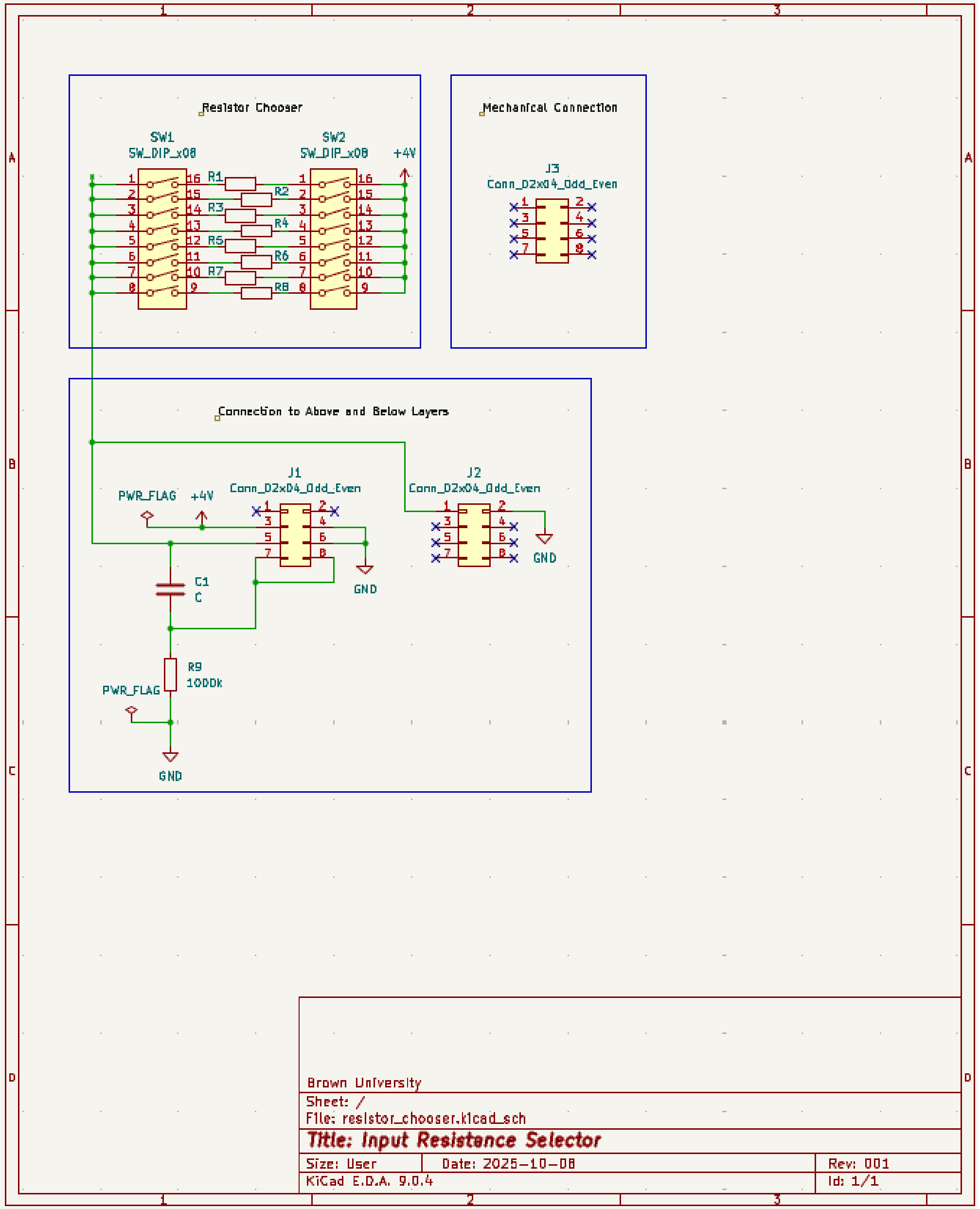
The first project I designed is a selectable input resistance circuit that allows us to control the effective bias voltage applied across an MTJ array during noise measurements. By selecting different input resistances, we can tune the bias conditions experienced by the MTJs, enabling exploration of how bias voltage affects their intrinsic noise characteristics.

Because even small amounts of additional electrical noise can compromise the sensitivity of the measurement, the circuit must introduce minimal noise of its own. Careful component selection, grounding, and shielding were therefore essential in its design. One main feature of the circuit is to electrically isolate unused resistors that would otherwise overwhelm the intrinsic noise measurement. The circuit is part of a larger multi-stage assembly and must integrate seamlessly with the subsystems above and below it:

- The upper stage connects to the MTJ array.
- The lower stage interfaces with the DAQ system and battery-powered voltage source, which includes low-pass filters and amplifiers for signal conditioning.

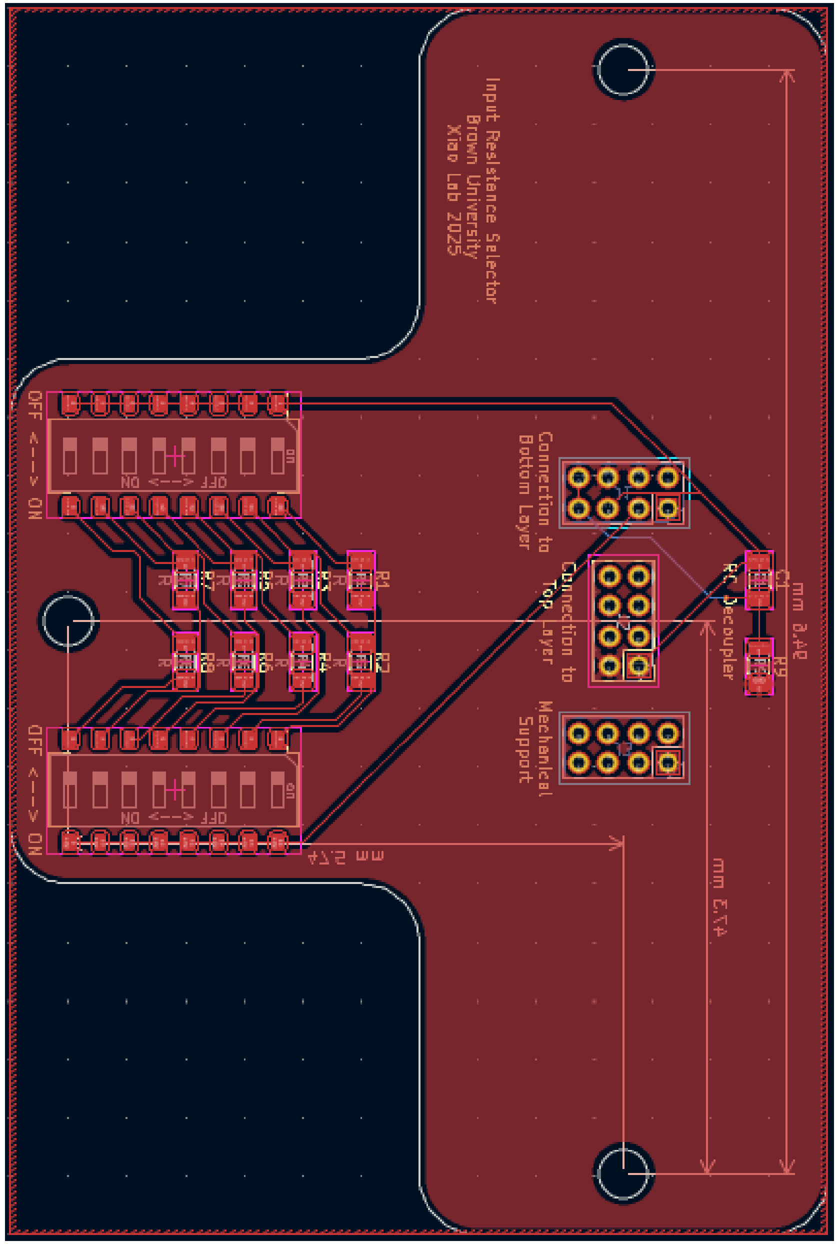
Design & Schematic

- 2 DIP switches to choose between discrete input bias voltages
- Electrical and mechanical connections to other stages
- Isolates thermal noise caused by resistors carrying no current
- Features RC rectifier stage to suppress low-frequency components in data acquisition



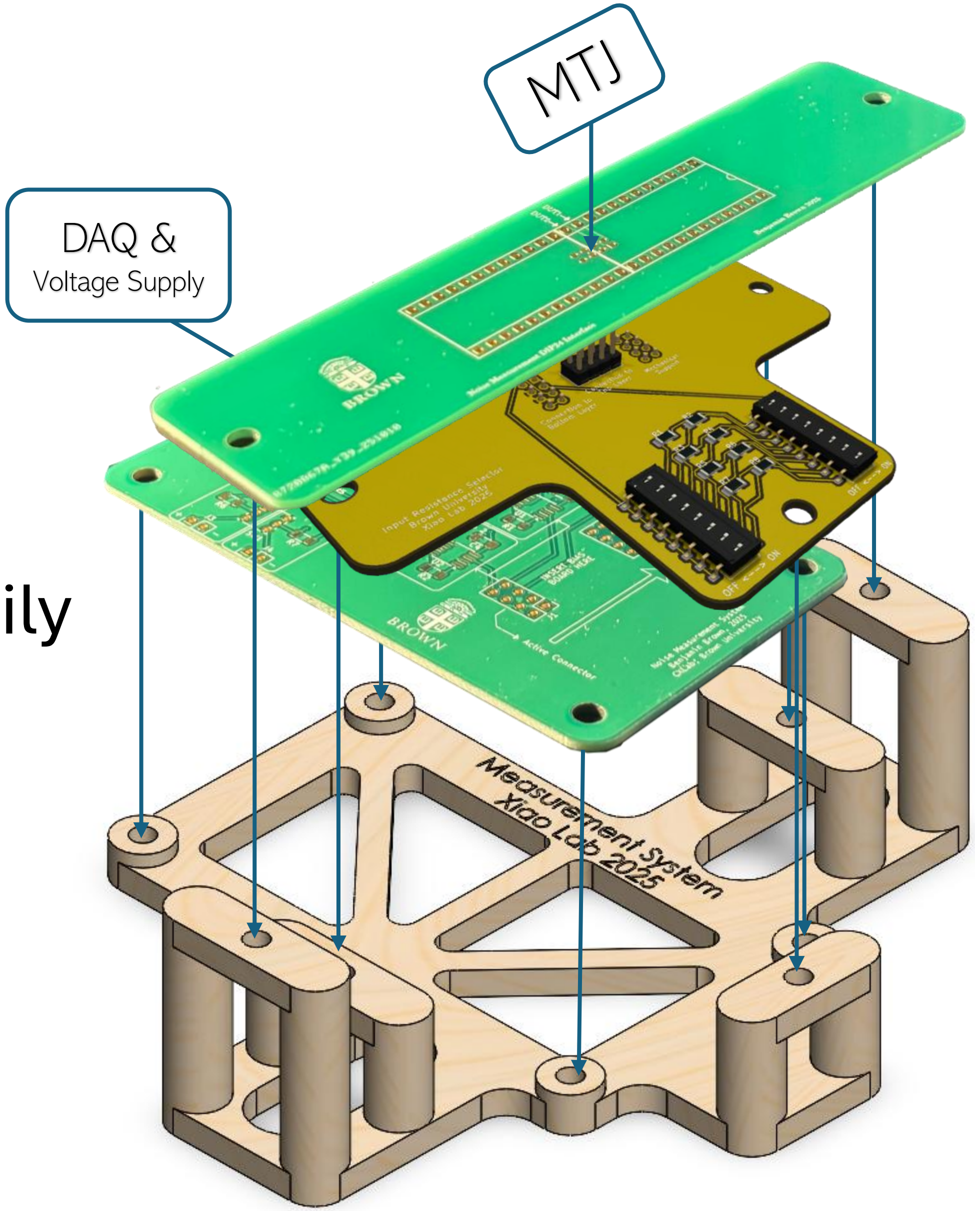
Circuit Board Design

- Short trace lengths to reduce parasitic capacitance and inductance
- Ground plane provides a low-impedance return path for signal from MTJ array
- Components and dimensions well marked for easy assembly and use



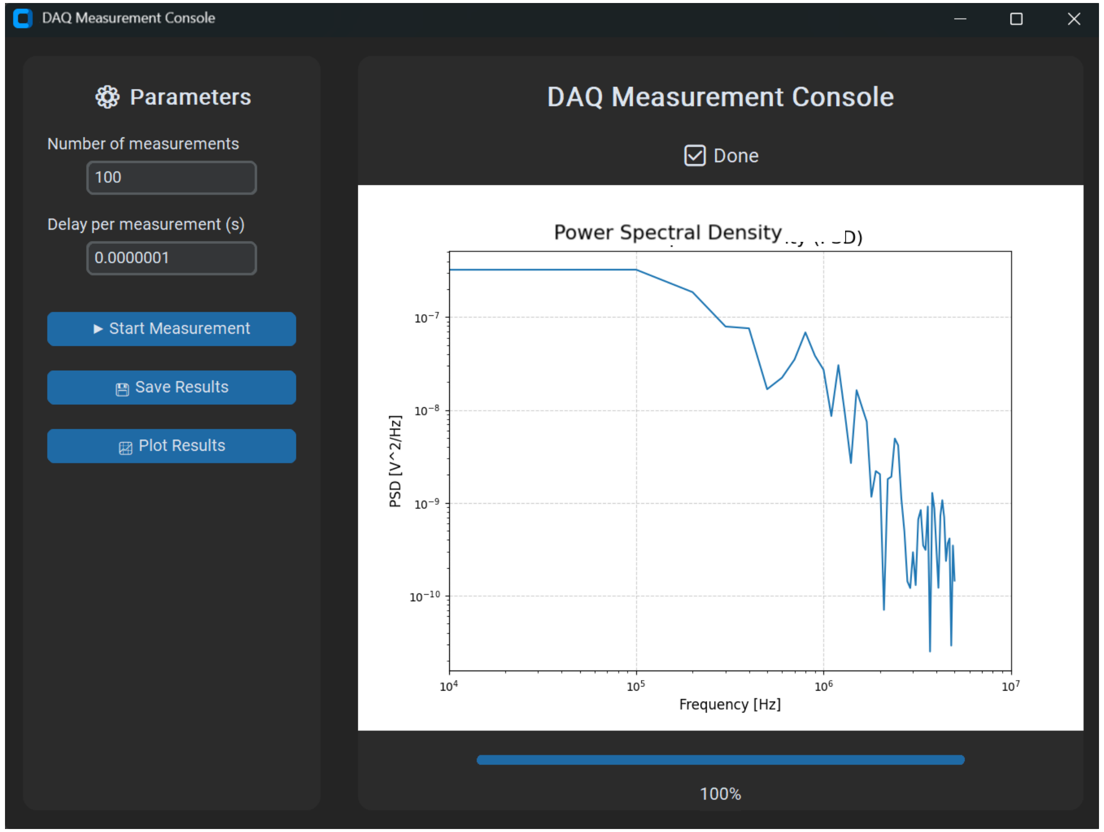
PCB Assembly

- DIP switches accessible without removing top layer board
- Designed a 3D printed mount to support PCBs so top layer can be easily swapped between measurements



Project: Measurement User Interface

- Making an interface to enable real time monitoring of measurements that can take hours/days to finish
- Once completed, GUI will upload live plots as data is collected for monitoring from outside Faraday cage and outside lab



FSAE Projects

I joined Brown's FSAE team in early 2024, machining random parts for different subsystems. Sophomore year, I started designing my own parts for the Suspension and Pedalbox, and as a Junior I am now the Lead Responsible Engineer for the Drivetrain subsystem. My design work on the drivetrain entails running dynamic simulations and structural analyses on components.

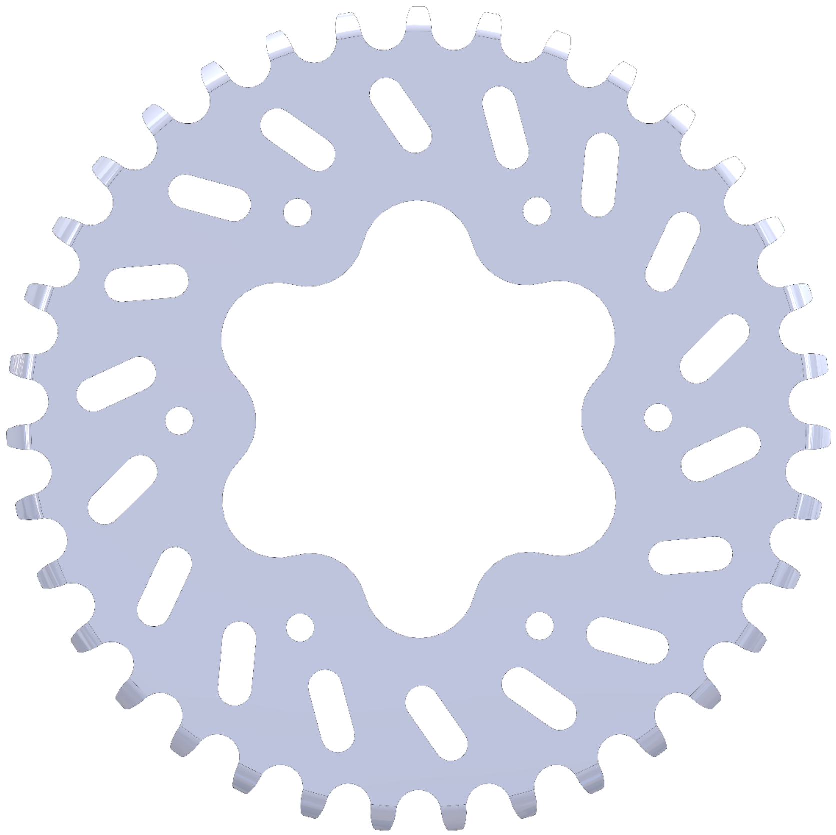
For purely acceleration simulations that do not require differential tuning, I write MATLAB scripts to compare vehicle parameter configurations. For simulations with turns, I have started using a lap sim software, where I can also tune the rear differential.

For structural analysis, I perform force calculations for all the components in the subsystem. I import my CAD drawings into ANSYS, where I perform static load case calculations.

Through January 2025, my subsystem team and I will machine and order different parts so that assembly can begin in late January.

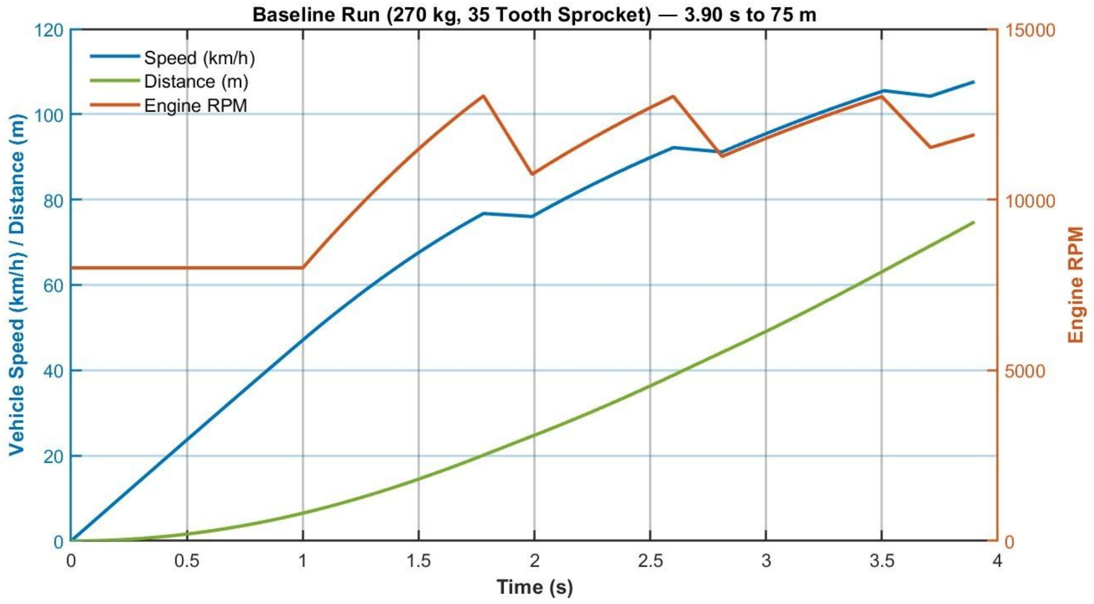
Project: Final Drive Ratio Optimization

- Wrote MATLAB scripts to sweep through vehicle parameters such as engine power, wheel slip torque, vehicle mass distribution, sprocket size, and shifting time.
- Want to optimize final drive ratio for a given vehicle and driver mass



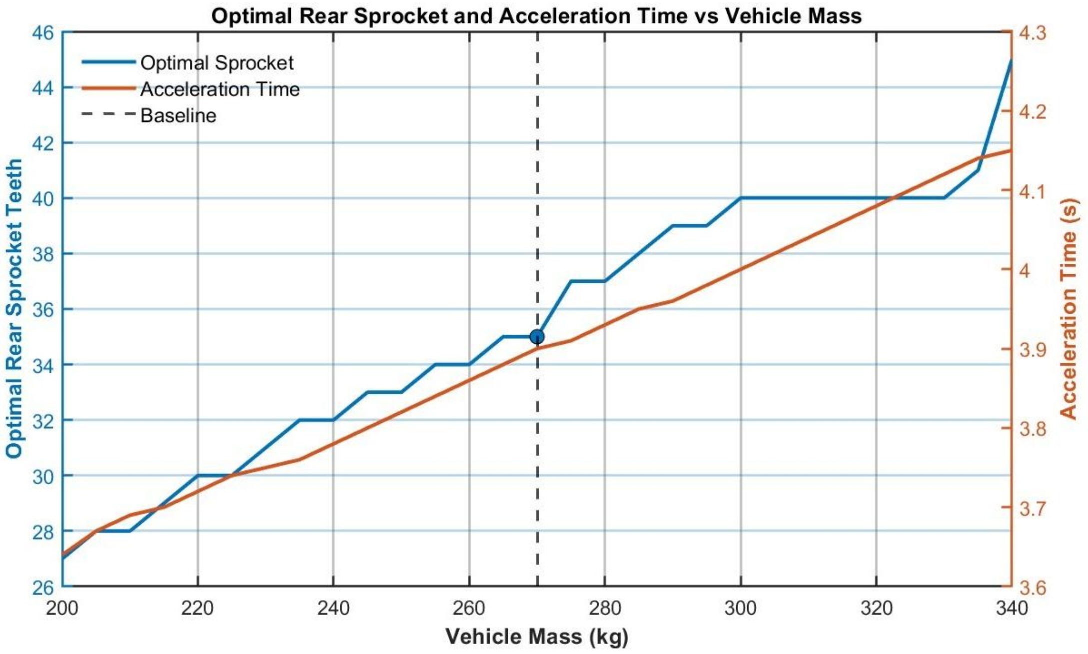
Baseline Acceleration Event Simulation

- Ran gear shift timing optimization simulation using estimated competition car and driver mass
- Optimal shift strategy starts in second gear and ends event in fifth gear

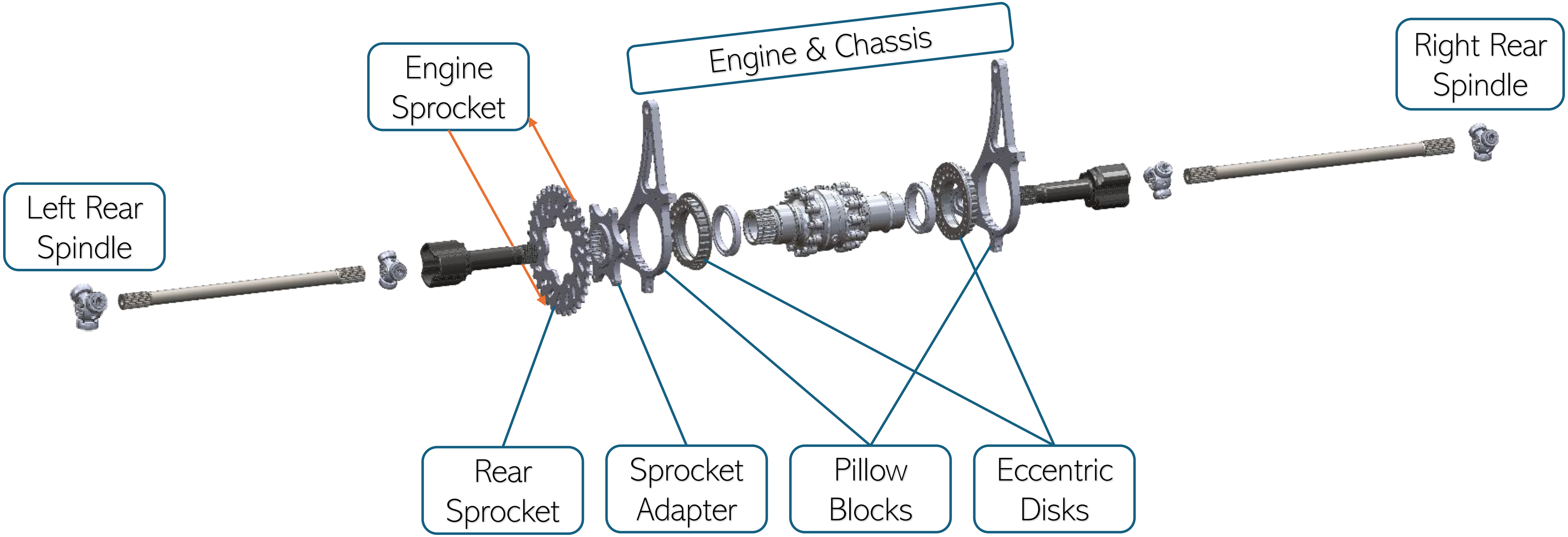


Acceleration Run Mass Sweep Simulation

- Swept through vehicle (driver) mass with different rear sprocket sizes
- Heavier vehicle benefits from shorter gearing (larger rear sprocket) and vice versa due
- Overall non-negligible change in 75-meter acceleration event time for changes in vehicle mass



Project: Drivetrain Structural Analysis



Drivetrain Structural Analysis

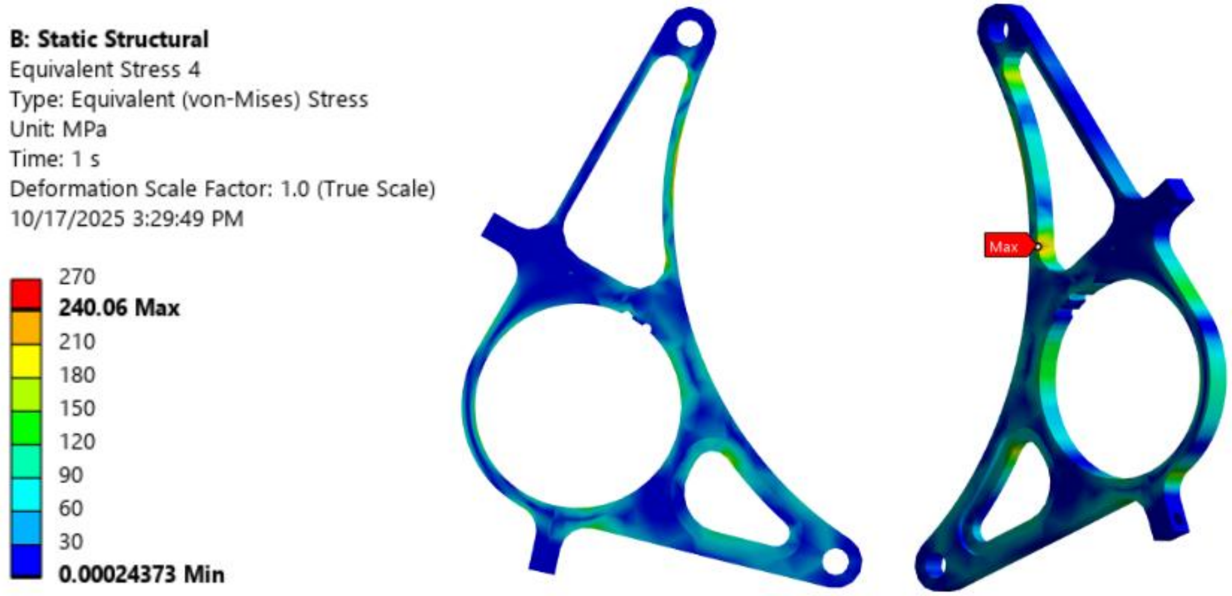
I am manufacturing the pillow blocks, eccentric bearing disks, rear sprocket, and sprocket adapter in house from Aluminum 7075 (ultimate-strength-limited)

Calculated maximum force vector on drivetrain components from engine torque curve and engine internal gear ratios

Currently collaborating with Engine lead on load case for a clutch drop that would exceed peak torque load on drivetrain

Left Pillow Block Structural Analysis

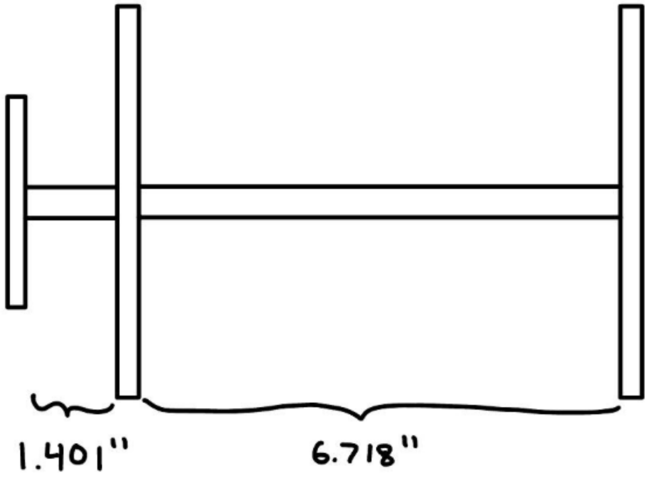
- FOS: Safety critical, replaceable
- Limited by 7075 ultimate strength
- Even stress distribution over supporting beams
- Good margin of safety (+0.12), weight reduced from last season

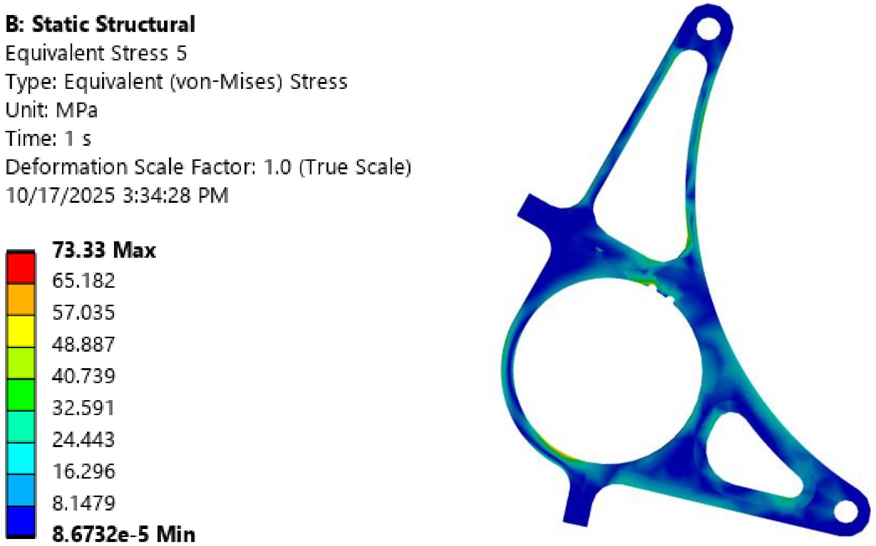


Loadcase	Solver	Analyst	Part	FOS (yield)	FOS (ultimate)	Yield Allowable	Ultimate Allowable	Ms_y (yield margin)	Ms_u (ultimate margin)
Peak Torque Chain Tension	ANSYS	B. Kovatchev	Left Pillow Block	1.25	2.0	235 MPa	270 MPa	**0.56**	**0.12**

Right Pillow Block Structural Analysis

- Left pillow block acts as lever pivot
- Overbuilt: must minimize mass

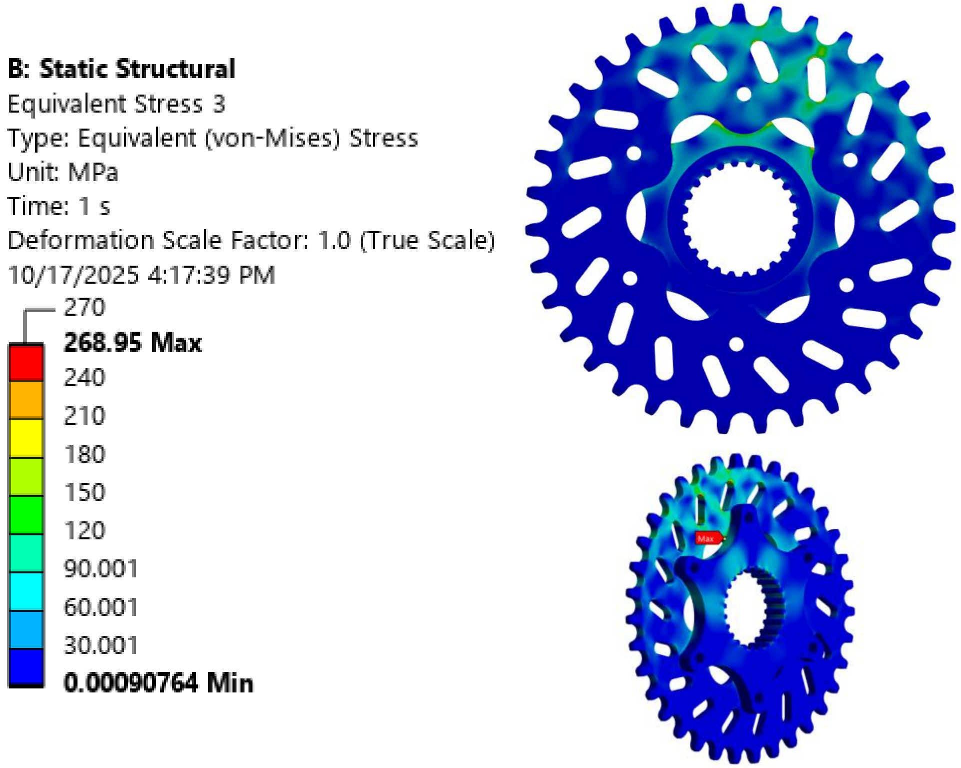




Loadcase	Solver	Analyst	Part	FOS (yield)	FOS (ultimate)	Yield Allowable	Ultimate Allowable	Ms_y (yield margin)	Ms_u (ultimate margin)
Peak Torque Chain Tension	ANSYS	B. Kovatchev	Right Pillow Block	1.25	2.0	235 MPa	270 MPa	**4.12**	**2.68**

Rear Sprocket & Adapter Structural Analysis

- FOS: Safety critical, replaceable
- Limited by 7075 ultimate strength
- Even stress distribution over teeth engaged with chain and connections between sprocket and adapter
- Excellent margin of safety (+0.004), weight minimized



Loadcase	Solver	Analyst	Part	FOS (yield)	FOS (ultimate)	Yield Allowable	Ultimate Allowable	Ms_y (yield margin)	Ms_u (ultimate margin)
Peak Torque Chain Tension	ANSYS	B. Kovatchev	Rear Sprocket	1.25	2.0	235 MPa	270 MPa	**0.39**	**0.004**

Project: Eccentric Bearing Disks

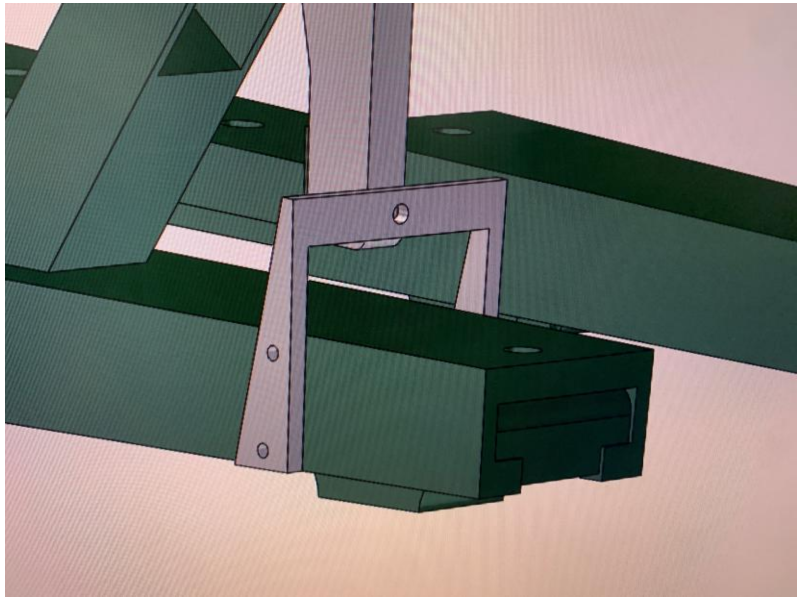
- Leading design process for rotating bearing disks to enable adjustable drivetrain position within pillow blocks and vehicle coordinates
- Taught drivetrain new members CAD and FEA basics in SolidWorks and ANSYS for eccentric disk design campaign
- Teaching new members manual and CNC machining principles to manufacture 2026 eccentric disks

Machined: Brake Pedal

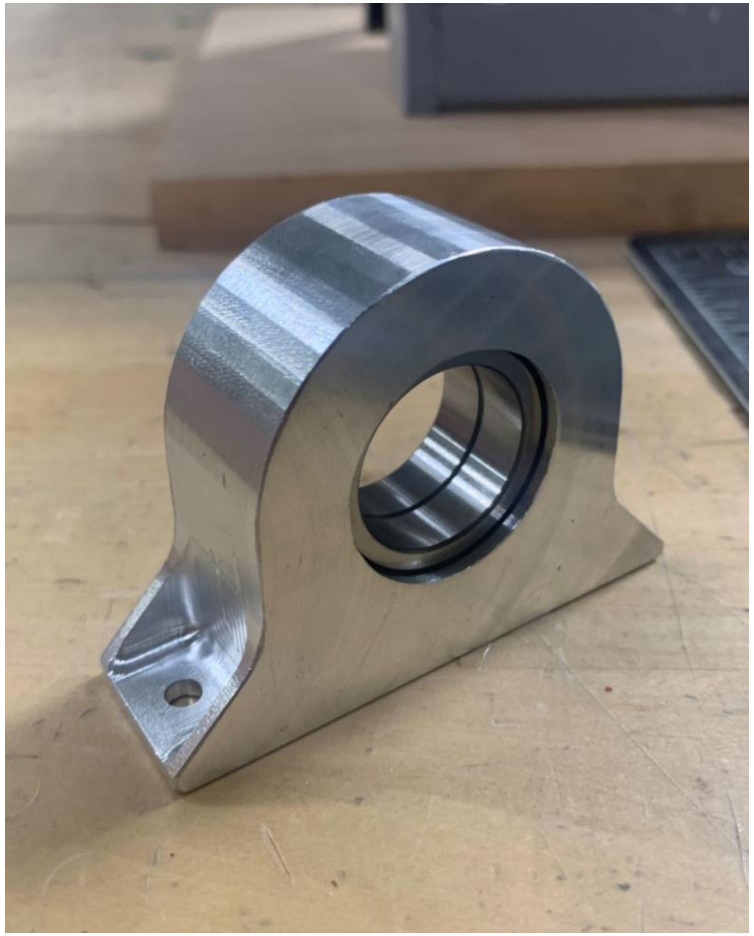
- Machined the brake pedal for the 2025 car with Tormach CNC Mill
- Prepared g-code with Fusion 360
- Bore for bias bar bearing
- Sandblasted for aesthetics

Machined: Throttle Stop

- Designed and manually machined stopper for throttle pedal on 2025 car
- Hole for throttle cable



Machined: Steering Bearing Housing



- CNC machined housing for steering wheel bearing on 2025 car
- Precision bore and fly cut surface finish

Personal Projects

Project: Cabin

Over the last two years, I have constructed a 12x12 ft cabin with a 6x12 ft deck area. Over the course of the project, I learned how to work with lumber, screws, saws, plywood, and roofing shingles. I learned how to pour concrete and mix cement and how to level out large surfaces. I learned about moisture control and insulation. I watched tons of videos online about similar projects and made a short YouTube series on building the foundation for the cabin.

While at the bottom of my portfolio, it is by no means a small endeavor. I am incredibly proud of where I have come with this project, and the best part is that I am still not finished.

The cabin has taken about 60 person-days to build, and I had a lot of help from friends and family. For their privacy I have only included pictures of the cabin and myself.

Foundation

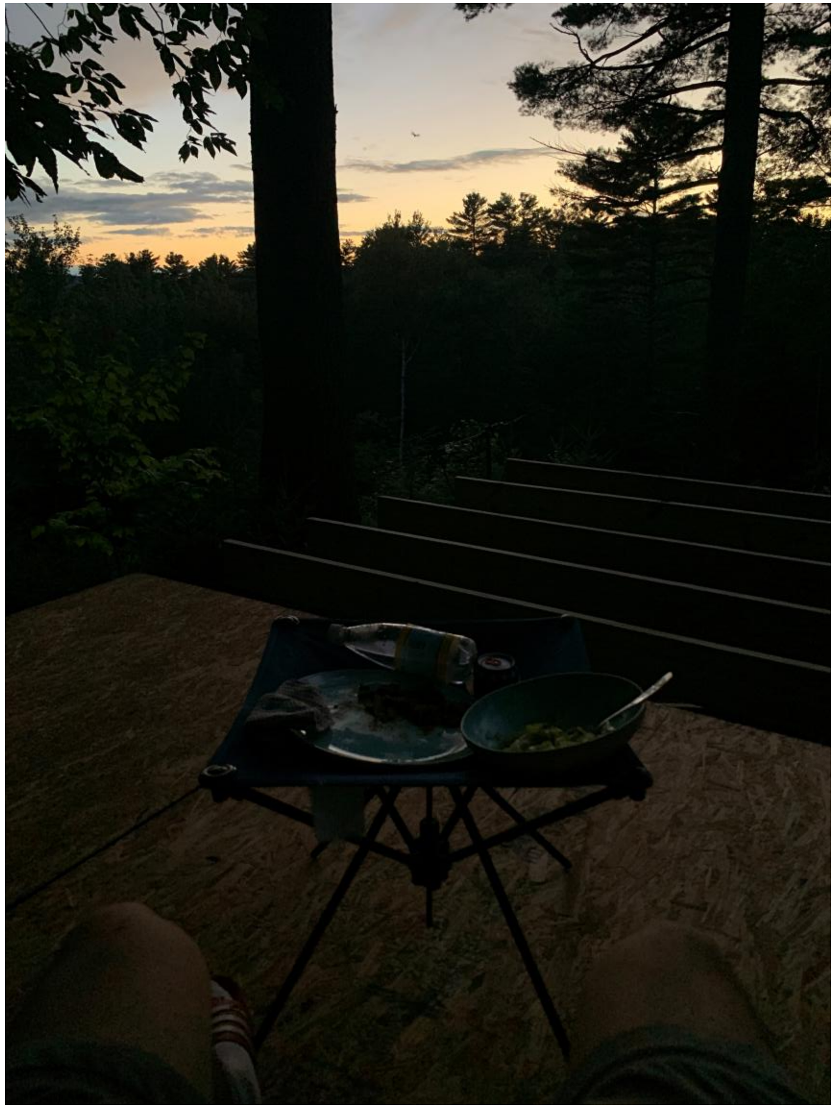
Site Clearing

Concrete + 8x8 Posts

Foundation Beams

Floor and Deck Joists

First Dinner on Deck

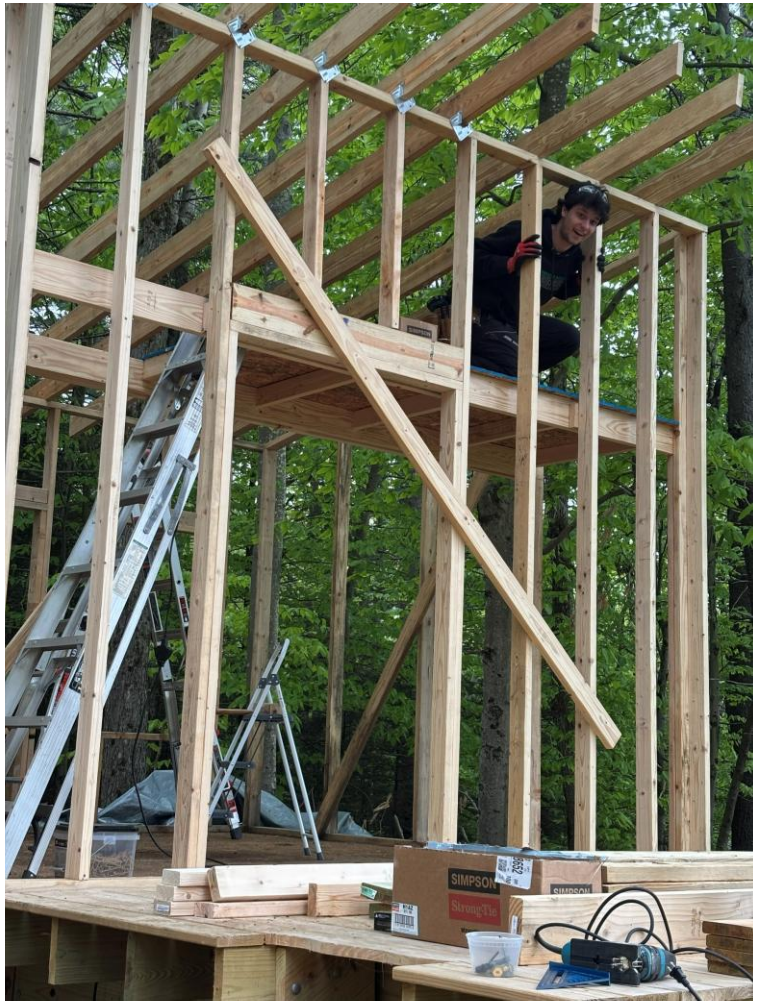


Framing

First Wall with Windows

Stairs to Deck

Loft

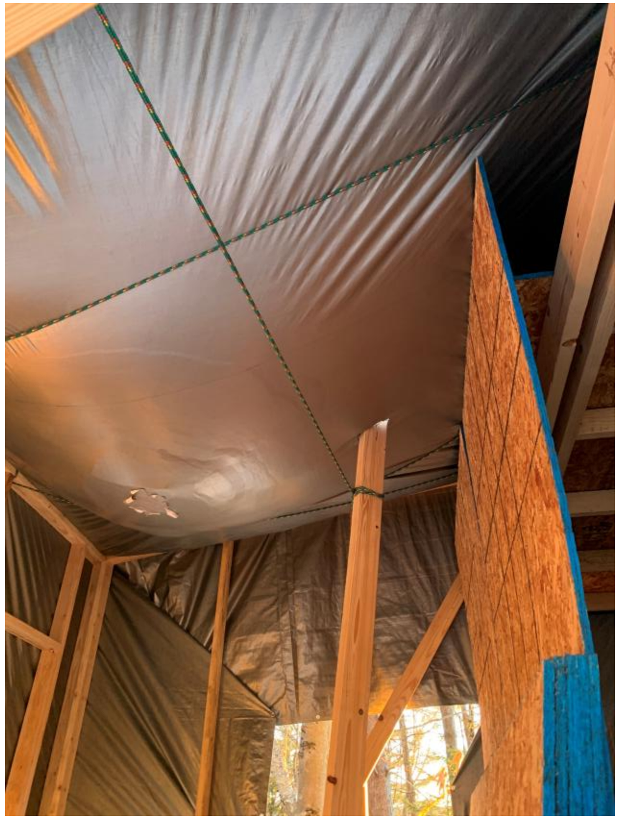


Winter 2024-25

Tarp

Snow

Sagging Tarp



Roofing

Upside Down T1-11 Siding

Plywood & Drip Edge

Roofing Felt & Asphalt Shingles

Finished Roof

Siding

Vapor Barrier

T1-11 Plywood Siding

Front View

Pictures

Rainy Day Siding Painting Studio

Setup for Friends Coming Over

Action Shot

Naming the Cabin

Next Steps: Winter 2025-26

- Build windows
- Finish interior
- Furnish with table, benches, chairs, bed in loft, and kitchenette

Thank You for Viewing

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