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I am a mechanical engineering student at Princeton University, pursuing a minor in Materials Science. I am also a Division I swimmer nationally annually ranked top 15 in my events.

My passion lies in mechanical design. I love developing a first-principles understanding of my engineering decisions. I am drawn to challenges at the intersection of theory and practical design.

Aerospace and Manufacturing Technology are particular areas of interest for me.

From a young age, watching rocket launches have always drawn my attention and I've always naturally seeked out aerospace knowledge. I believe it's the ultimate frontier and the most inspiring industry in the world.

Reflecting on my practical engineering experiences, my most rewarding moments come from the fabrication process. I see manufacturing as an enabling field. Advances in how we make things not only expand the design space for engineers, but also shape the economics that drive technologies to spread from the bottom up, making them more accessible to all.

SLM/PμSL Printer

Main Takeaways:

- Intern at USC's Center for Advanced Manufacturing
- Responsibility over the development of their SLM Printing Project with an advisor
- Efficiently fabricating micro-scale photopolymer overhang structures.
- Feasibility assessments
- Mechanical system & simple UX design
- Optical setup & alignment
- Designing calibration tests & setups

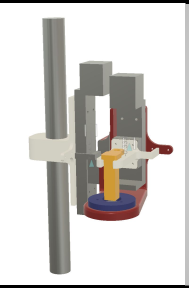
I designed and built a variable-depth, scanning projection micro-stereolithography (PuSL) printer capable of efficiently fabricating micro-scale photopolymer overhang structures.

The lab was given a new SLM product by the optical company, Santec, with the task of assessing potential applications in 3D Printing.

Through testing, I discovered SLMs could be a promising platform for 3D printing because of smooth image scanning, conservation of laser energy in varying image sizes, and features like pseudo blaze gratings and fresnel lenses.

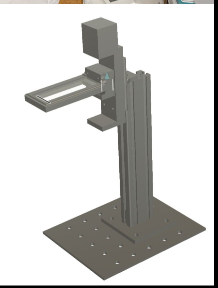
My advisor pointed out present difficulties of microfluidic channel fabrication with photolithography. An SLM allows for predictably varied energy density of images and thus useful variable-depth printing. Rather than printing one thin layer at a time of an overhang structure, an SLM printer can print the whole overhang at once by scanning a smaller, but higher energy density image.

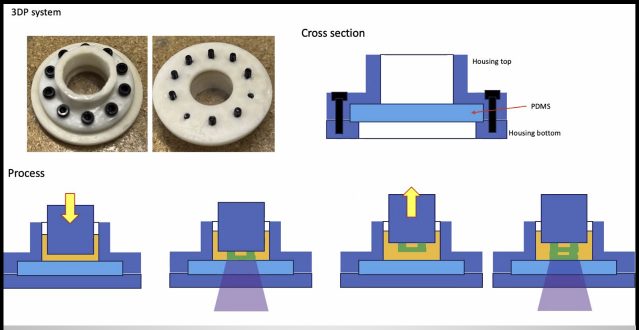
Entire Setup



Two-Stage Print System

Of note, I split the two stages onto separate mounting posts Post-CAD due to observed compounding vibrations. Like industry SLA machines and for quick post-processing, I created a quick-release print surface

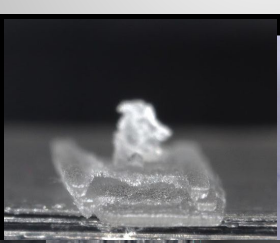


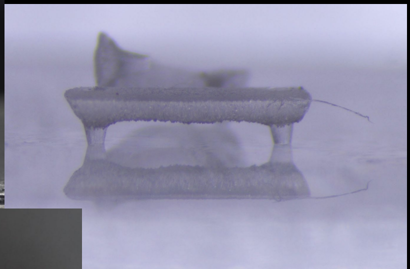


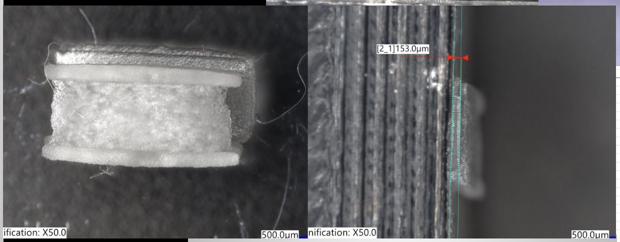
PDMS Housing

After literature review, I decided to use PDMS CLIPs tech as my printing interface to minimize separation force on very small overhang features.

The housing needed a flange and made of photopolymer resin to be water-tight

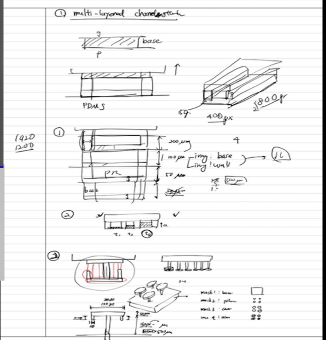


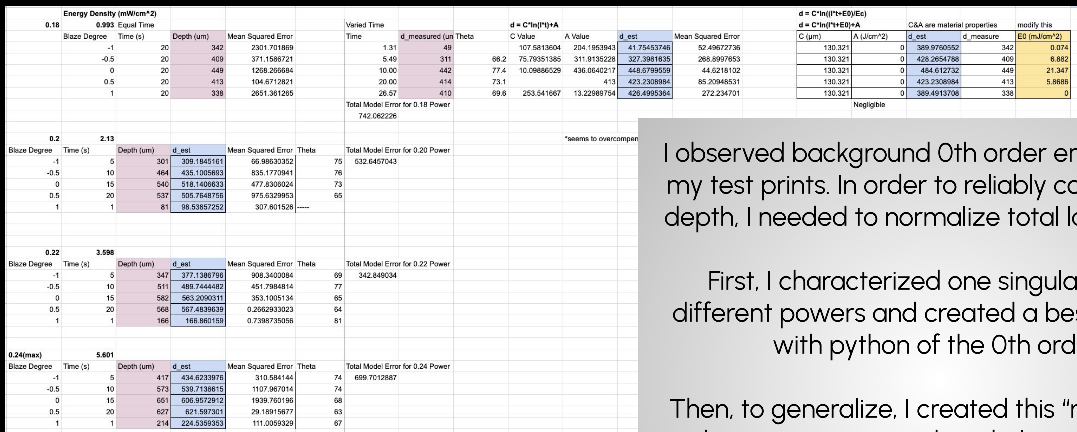




Micro/Millifluidic Channel

Various Print Conditions





	Energy Density (mW/cm^2)				
0.18	0.993	Equal Time			
	Blaze Degree	Time (s)	Depth (um)	Mean Squared Error	
	-1	20	342	2301.701869	
	-0.5	20	409	371.1586721	
	0	20	449	1268.266684	
	0.5	20	413	104.6712821	
	1	20	338	2651.361265	
0.2	2.13				
Blaze Degree	Time (s)	Depth (um)	d_est	Mean Squared Error	Theta
-1	5	301	309.1845161	66.98630352	75
-0.5	10	464	435.1005693	835.1770941	76
0	15	540	518.1406633	477.8306024	73
0.5	20	537	505.7648756	975.6329953	65
1	1	81	98.53857252	307.601526	-----
0.22	3.598				
Blaze Degree	Time (s)	Depth (um)	d_est	Mean Squared Error	Theta
-1	5	347	377.1386796	908.3400084	69
-0.5	10	511	489.7444482	451.7984814	77
0	15	582	563.2090311	353.1005134	65
0.5	20	568	567.4839639	0.2662933023	64
1	1	166	166.860159	0.7398735056	81
0.24(max)	5.601				
Blaze Degree	Time (s)	Depth (um)	d_est	Mean Squared Error	Theta
-1	5	417	434.6233976	310.584144	74
-0.5	10	573	539.7138615	1107.967014	74
0	15	651	606.9572912	1939.760196	68
0.5	20	627	621.597301	29.18915677	63
1	1	214	224.5359353	111.0059329	67

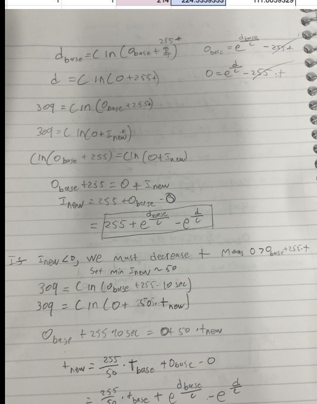
Varied Time			d = C*ln(I*t)+A			
Time	d_measured (um	Theta	C Value	A Value	d_est	Mean Squared Error
1.31	49		107.5813604	204.1953943	41.75453746	52.49672736
5.49	311	66.2	75.79351385	311.9135228	327.3981635	268.8997653
10.00	442	77.4	10.09886529	436.0640217	448.6799559	44.6218102
20.00	414	73.1		413	423.2308984	85.20948531
26.57	410	69.6	253.541667	13.22989754	426.4995364	272.234701
Total Model Error for 0.18 Power						
742.062226						
				*seems to overcompen		
Total Model Error for 0.20 Power						
532.6457043						
Total Model Error for 0.22 Power						
342.849034						
Total Model Error for 0.24 Power						
699.7012887						

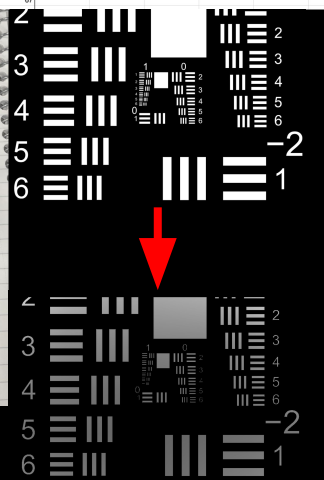
d = C*ln((I*t+E0)/Ec)				
d = C*ln(I*t+E0)+A		C&A are material properties		modify this
C (µm)	A (J/cm^2)	d_est	d_measure	E0 (mJ/cm^2)
130.321	0	389.9760552	342	0.074
130.321	0	428.2654788	409	6.882
130.321	0	484.612732	449	21.347
130.321	0	423.2308984	413	5.8686
130.321	0	389.4913708	338	0
	Negligible			

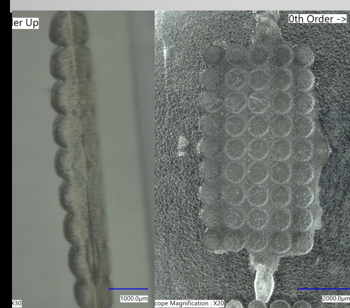
I observed background 0th order energy during my test prints. In order to reliably control curing depth, I needed to normalize total laser energy.

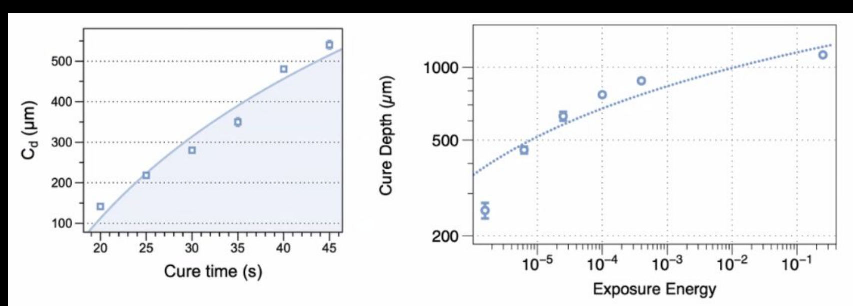
First, I characterized one singular row at different powers and created a best fit model with python of the 0th order.

Then, to generalize, I created this "needle" test to characterize across the whole image plane in low fidelity. I then created code to find a best-fit model across all needles and generate a grayscale filter to counteract the 0th Order image. The SLM focuses less energy on darker portions.

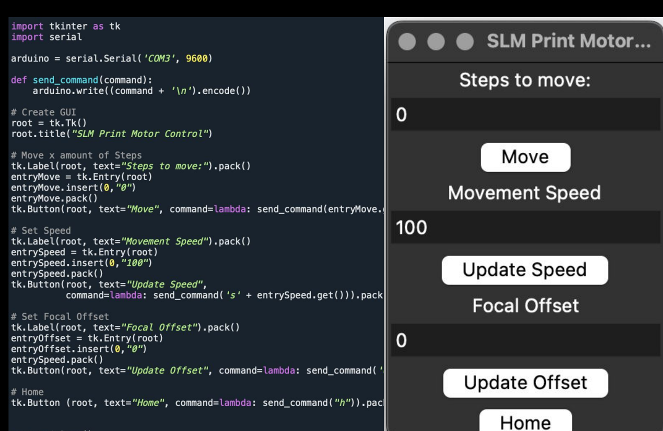








Final Curing Depth Characterization



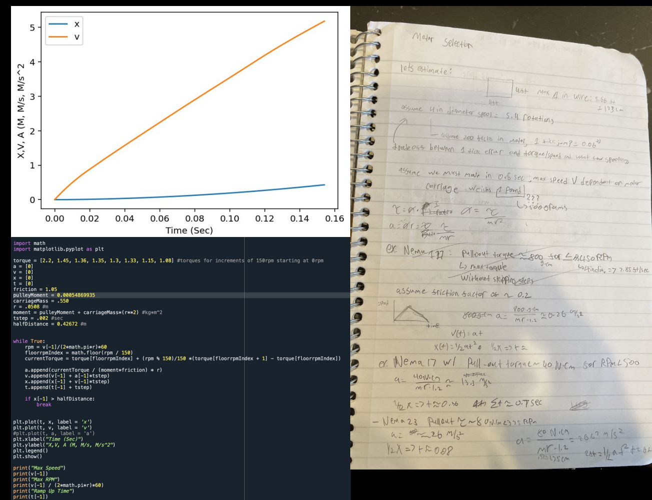
```python
import tkinter as tk
import serial

arduino = serial.Serial('COM3', 9600)

def send_command(command):
    arduino.write((command + '\n').encode())

# Create GUI
root = tk.Tk()
root.title("SLM Print Motor Control")

# Move x amount of Steps
tk.Label(root, text="Steps to move:").pack()
entryMove = tk.Entry(root)
entryMove.insert(0,"0")
entryMove.pack()
tk.Button(root, text="Move", command=lambda: send_command(entryMove.

# Set Speed
tk.Label(root, text="Movement Speed").pack()
entrySpeed = tk.Entry(root)
entrySpeed.insert(0,"100")
entrySpeed.pack()
tk.Button(root, text="Update Speed",
          command=lambda: send_command('s' + entrySpeed.get())).pack

# Set Focal Offset
tk.Label(root, text="Focal Offset").pack()
entryOffset = tk.Entry(root)
entryOffset.insert(0,"0")
entrySpeed.pack()
tk.Button(root, text="Update Offset", command=lambda: send_command('

# Home
tk.Button (root, text="Home", command=lambda: send_command("h")).pac

root.mainloop()
```


Motor Control GUI

2D Basketball Hoop

Main Takeaways:

- Personal Project starting in Summer '25
- Portability and cost requirements led to 2D cable-driven parallel hoop
- Full ownership & self-education of CV, power electronics
- Development of motor control algorithms
- In final design stages & CV integration
- MVP by mid-November



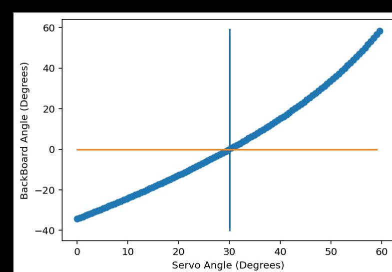
Motor Simulation for Motor Selection

Inspired by *Stuff Made Here*, I am building a ball-seeking mini basketball hoop. Constrained by my dorm setting, I prioritized portability and low cost. This led to a cable-driven design with motors in a central box and pulleys on suction cups.

To meet the ball in time, I budgeted for code, electronics, and CV latency, and simulated motor response to move the hoop ~3 ft in ½ second. An actuated backboard was added to catch any AoA trajectory. To reduce costs, I emphasized sound design choices and rigorous simulation before hardware development.

I am now developing profile-prediction code to integrate my OpenCV code and updating my carriage to use 4 motors. I initially planned for 2 opposing motors with reversed pulleys but had overlooked a simple geometric impossibility. Though more expensive, I will now use 4 motors over 3 to increase catch area, improve carriage weight symmetry, and avoid control singularities when wires become collinear. My target is an MVP by mid-November.

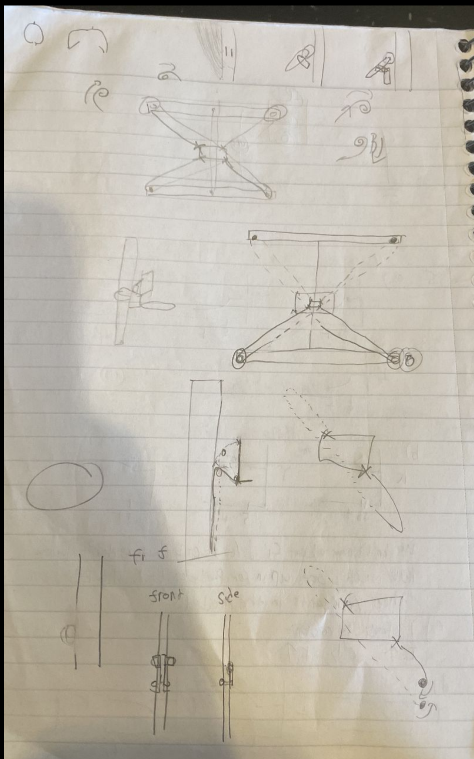
This project has underscored the value of peer design review and, outside a structured robotics setting, has taught me much about motor control, electronics, system integration, and computer vision.



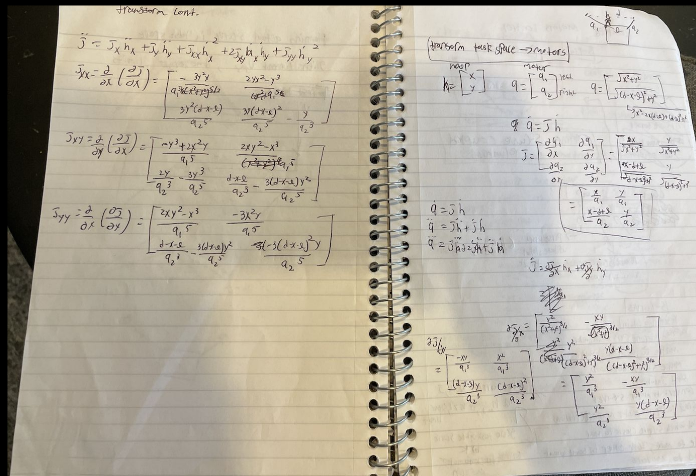
Backboard Servo to θ Relation

Cable-driven Carriage 1st Design

Rail System 1st Design

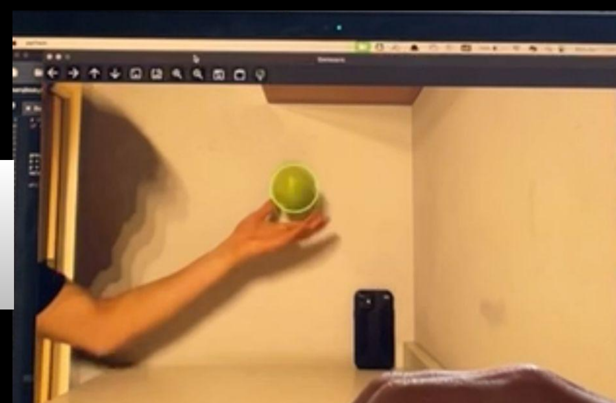


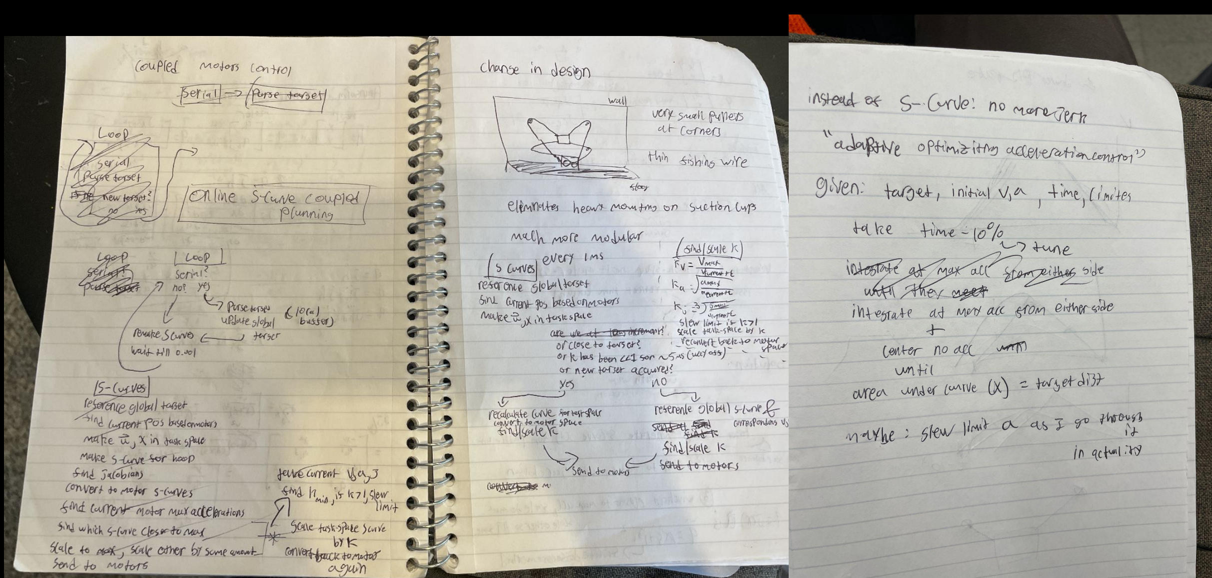
Some Design Sketches & Brainstorming



Jacobian Transformations from Carriage Frame to Motor Frame

OpenCV Position and Velocity tracking





Online S-curve Planning & Motor Control algorithm

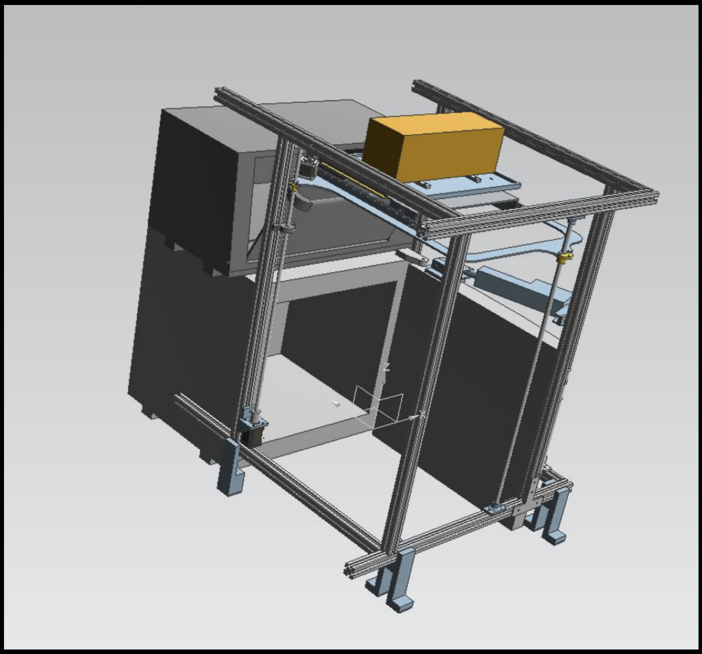
A challenge of having live target updating logic and balancing S-curve complexity and smoothness. To solve this, I developed my own <u>tunable simplified S-curve planner</u>. To reach max motor speeds, I <u>live update motor accelerations</u> based on torque curves

More to Come...

Thermal Cycling

Main Takeaways:

- Solo Independent Work Project to develop open-source cost-effective thermal cycling system
- To test 3U Cubesats and develop testing procedures based on orbital parameters
- Onshape & self-taught Siemens NX
- Advised by Mike Galvin - Principal Mechanical Engineer of NASA's SWAPI instrument and former Lockheed ME



At thermal extremes, most workmanship and design issues expose themselves and low-fidelity calibration of thermal performance changes can also be achieved for the cubesat scale. As such, to further reduce costs for student cubesat groups, I am using a toaster oven(>100c) and laboratory grade freezer (~-60c). Working with Mike Galvin has been an incredible experience as he exposes me to the intricacies of thermal simulation, in-space actuator design, and all other space-related designs I am interested in.

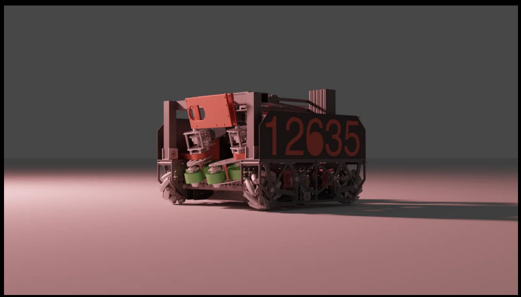
More to Come...

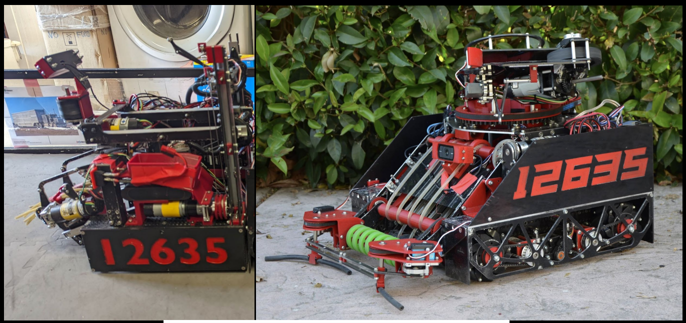
Kuriosity Robotics

Main Takeaways:

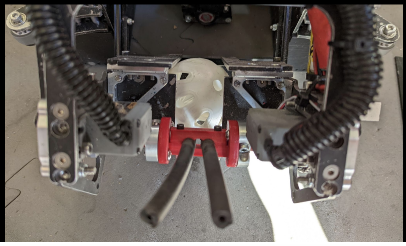
- Hardware lead during Transitional Period
- Hardware Team member for 4 years
- CAD Design, CNCing, 3D printing, FEA
- Face Shield Initiative production coordination

On my high school FIRST robotics team, I worked in a **small team of ~5** designing, learning and building 5 robots. Starting with simple COTS building systems, we self-taught ourselves the **power of CAD and CNC/3D printing manufacturing**. Our work was proudly recognized by winning the **World Championships Design Award**. My Senior Year, as the team entered a major transitional period and as Hardware Lead, I **led hardware knowledge transfer initiatives**. With many hardware tasks to accomplish, we often worked in conjunction with each other but the following are some smaller designs I had greatest ownership over.

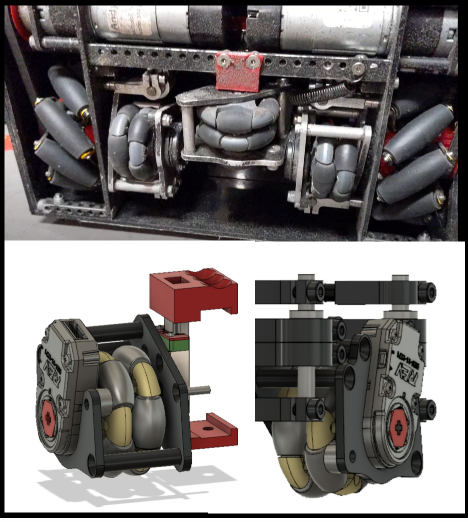




Our last 3 robots

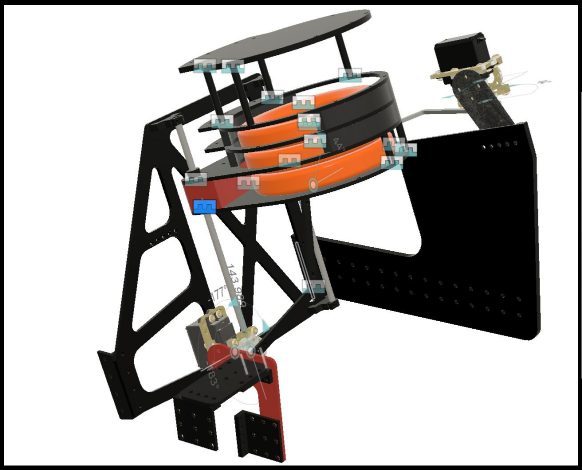


Ball & Cube Intake
Compact Intake I designed to rapidly collect plastic balls and cubes with passive transfer mechanism to reduce complexity.

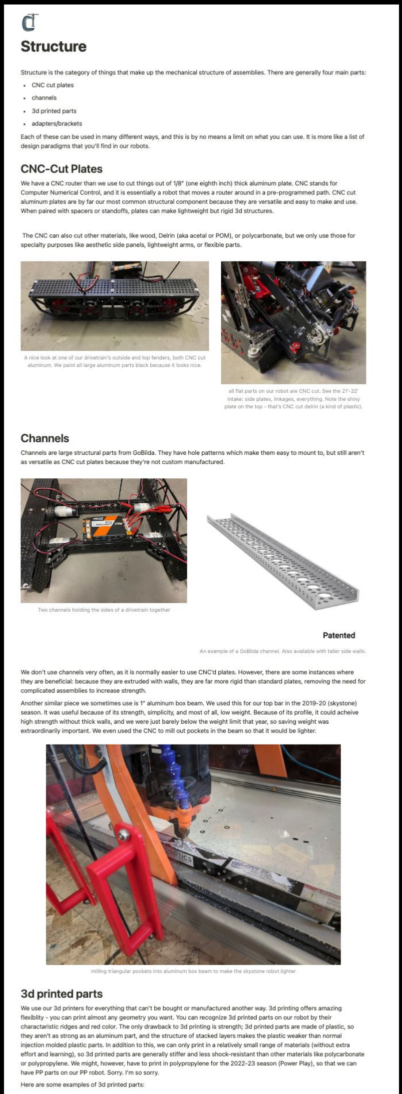


Odometry Pods
To create data redundancy, 3 odometry pods were used. To fit in a small drivetrain, I developed 3, consistently tensioned, compact pods on linear rails

Linear Slide System
Misumi linear slide system developed in-house over the years to extend 2ft in <2 seconds



Hopper Transfer
Needed to transfer rings from intake to shooter as quickly as possible to reduce cycle times. Hopper-linkage system slides on linear rails



Structure

Structure is the category of things that make up the mechanical structure of assemblies. There are generally four main parts:

- CNC cut plates
- channels
- 3d printed parts
- adapters/brackets

Each of these can be used in many different ways, and this is by no means a limit on what you can use. It is more like a list of design paradigms that you'll find in our robots.

CNC-Cut Plates

We have a CNC router than we use to cut things out of 1/8" (one eighth inch) thick aluminum plate. CNC stands for Computer Numerical Control, and it is essentially a robot that moves a router around in a pre-programmed path. CNC cut aluminum plates are by far our most common structural component because they are versatile and easy to make and use. When paired with spacers or standoffs, plates can make lightweight but rigid 3d structures.

The CNC can also cut other materials, like wood, Delrin (aka acetal or POM), or polycarbonate, but we only use those for specialty purposes like aesthetic side panels, lightweight arms, or flexible parts.

A nice look at one of our drivetrain's outside and top fenders, both CNC cut aluminum. We paint all large aluminum parts black because it looks nice.

all flat parts on our robot are CNC cut. See the 21'-22' intake: side plates, linkages, everything. Note the shiny plate on the top - that's CNC cut delrin (a kind of plastic).

Channels

Channels are large structural parts from GoBilda. They have hole patterns which make them easy to mount to, but still aren't as versatile as CNC cut plates because they're not custom manufactured.

Two channels holding the sides of a drivetrain together

Patented

An example of a GoBilda channel. Also available with taller side walls.

We don't use channels very often, as it is normally easier to use CNC'd plates. However, there are some instances where they are beneficial: because they are extruded with walls, they are far more rigid than standard plates, removing the need for complicated assemblies to increase strength.

Another similar piece we sometimes use is 1" aluminum box beam. We used this for our top bar in the 2019-20 (skystone) season. It was useful because of its strength, simplicity, and most of all, low weight. Because of its profile, it could acheive high strength without thick walls, and we were just barely below the weight limit that year, so saving weight was extraordinarily important. We even used the CNC to mill out pockets in the beam so that it would be lighter.

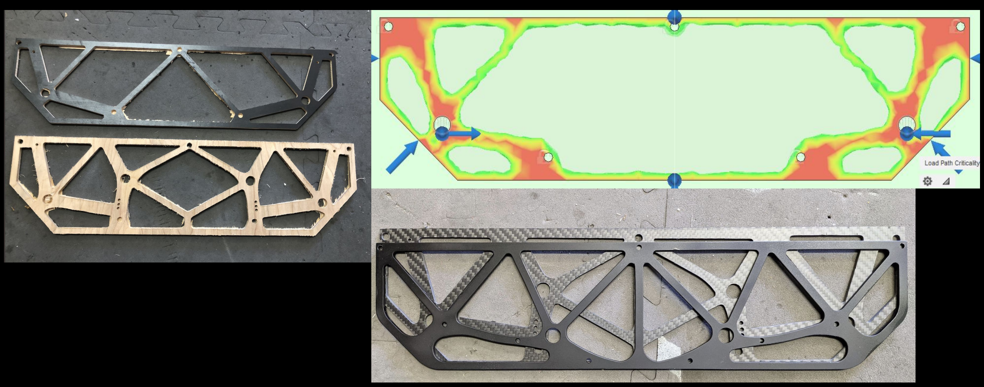
milling triangular pockets into aluminum box beam to make the skystone robot lighter

3d printed parts

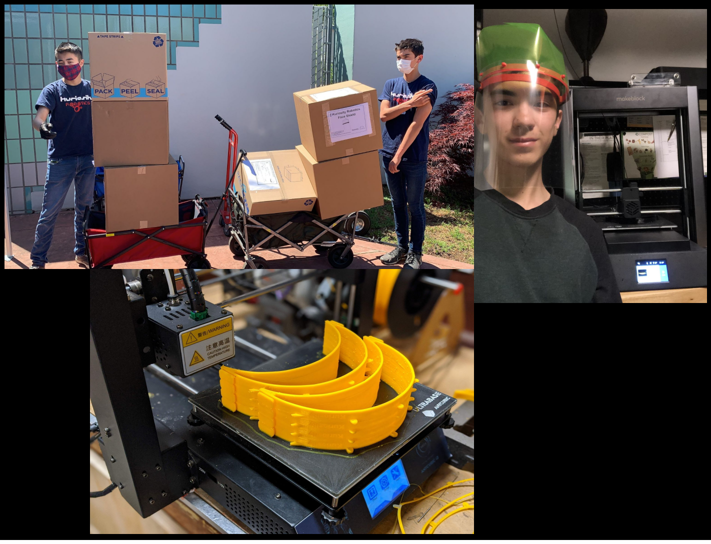
We use our 3d printers for everything that can't be bought or manufactured another way. 3d printing offers amazing flexiblity - you can print almost any geometry you want. You can recognize 3d printed parts on our robot by their charactaristic ridges and red color. The only drawback to 3d printing is strength; 3d printed parts are made of plastic, so they aren't as strong as an aluminum part, and the structure of stacked layers makes the plastic weaker than normal injection molded plastic parts. In addition to this, we can only print in a relatively small range of materials (without extra effort and learning), so 3d printed parts are generally stiffer and less shock-resistant than other materials like polycarbonate or polypropylene. We might, however, have to print in polypropylene for the 2022-23 season (Power Play), so that we can have PP parts on our PP robot. Sorry. I'm so sorry.

Here are some examples of 3d printed parts:

Sample of Hardware Documentation I did as Lead

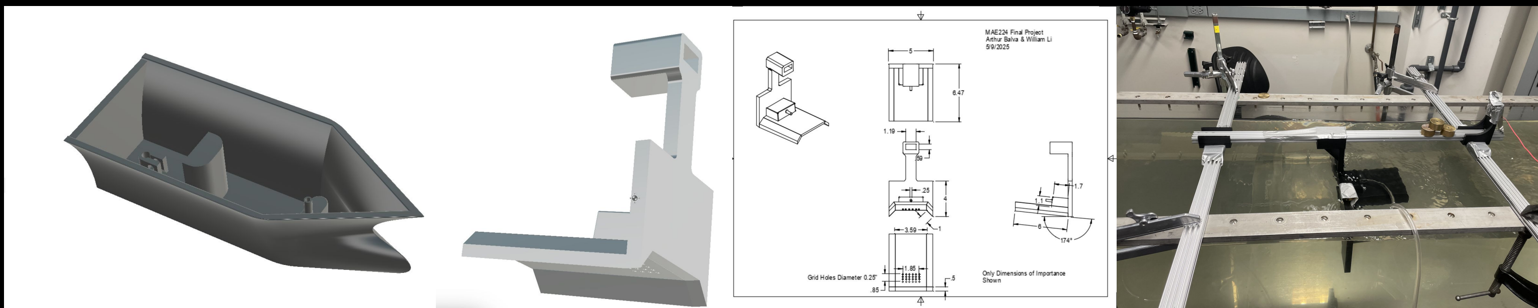


Drivetrain Fenders
We consistently hit weight limits and wanted to increase driving speed. I used FEA to create lighter fender designs. I prototyped on wood, then aluminum, and explored carbon fiber CNCing

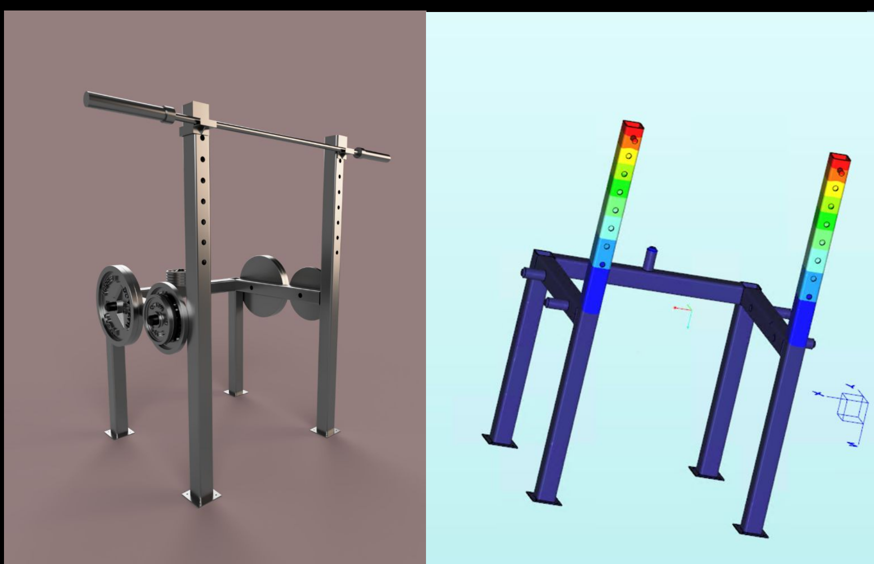


Face Shield Initiative
During COVID, we took on a very fulfilling project to donate 5000+ face shields. I helped design the ergonomic and cost-effective face shields, and focused on coordinating production and delivery

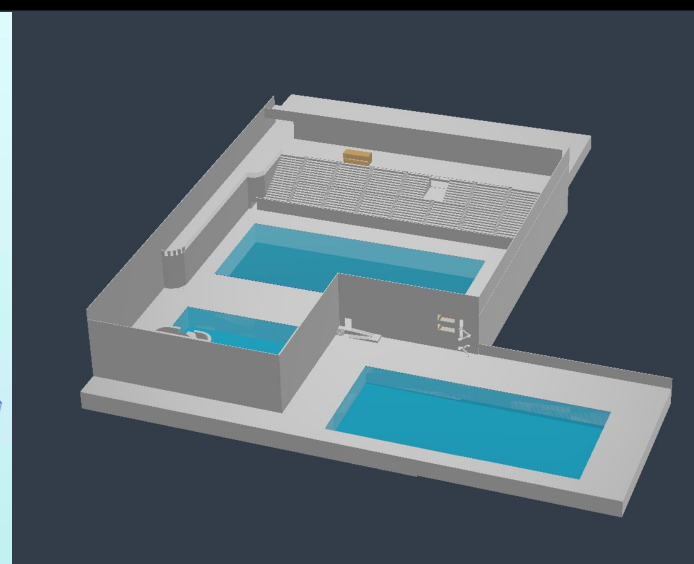
Miscellaneous



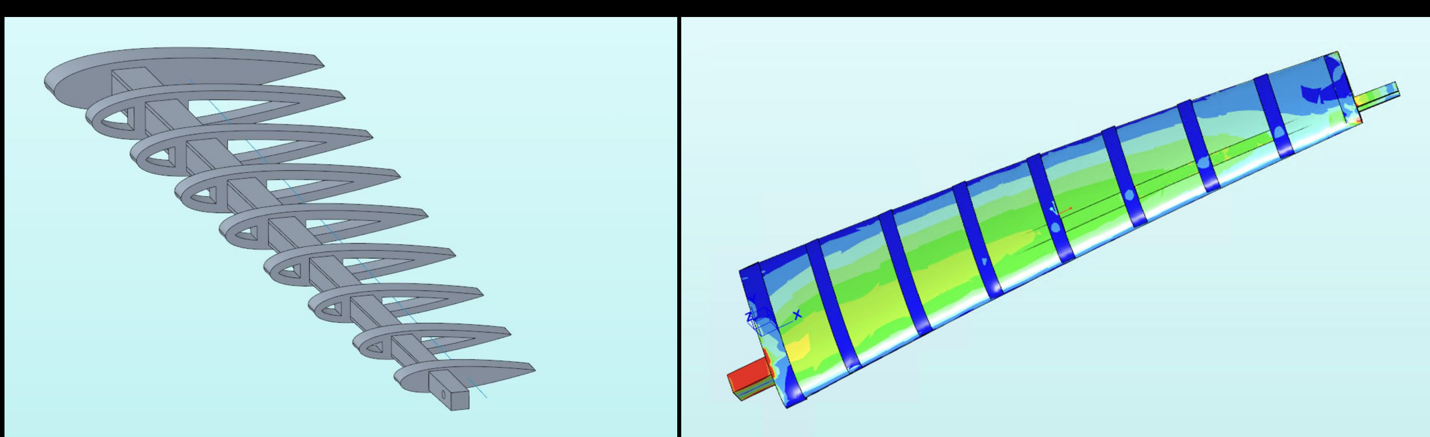
Boat Models to analyze Air Cavity Systems for open-ended Class Project
Flat Sided iteration created to create readable force outputs with flow limitations of the channel



Weight Rack Design & Analysis for Individual Class Project



Aquatic Facility Renovation Proposal for my Swim Team



Group Project to design High-Strength Aircraft Wing
I designed, analyzed, and manufactured the skin and bulkheads