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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 ranked top 15 in my events annually.

My passion lies in mechanical design, but even more in developing a first-principles understanding of the science that underpins my engineering decisions. I am drawn to challenges at the intersection of theory and practical design.

I have experience working in an additive manufacturing lab, FIRST robotics, personal projects, and am getting involved in a cubesat group here at Princeton.

Manufacturing technology is a particular area of interest for me. Looking back on my 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 accessible to all.

SLM/P μ SL Printer



Entire Setup

Main Takeaways:

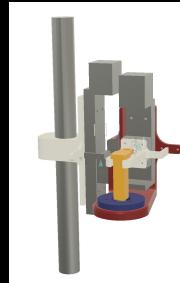
- Intern at USC's Center for Advanced Manufacturing
- Responsibility over the development of their SLM Printing Project with an advisor
- Efficiently fabricating micro-scale photopolymer overhang structures.
- Feasibility assessments
- Mechanical system & simple UX design
- Optical setup & alignment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

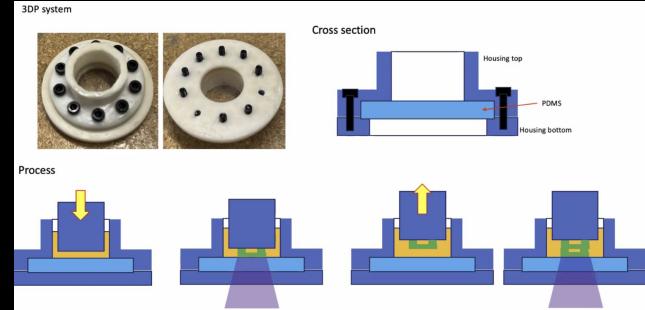
Through testing, I discovered SLMs could be a promising platform for 3D printing because of smooth image scanning, conservation of laser energy in varying image sizes, and features like pseudo blaze gratings and fresnel lenses.

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 structure at once by scanning a smaller but higher energy density image.



Two-Stage Print System

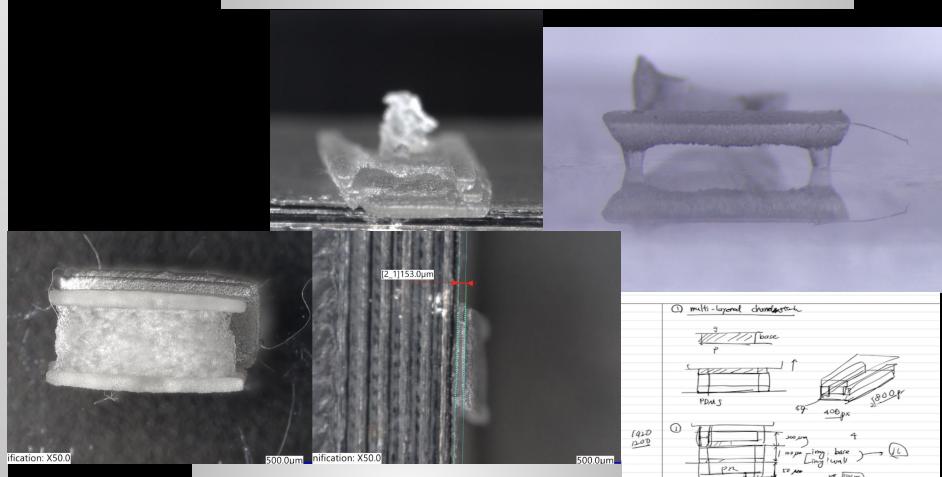
Of note, I split the two stages onto separate mounting posts Post-CAD due to observed compounding vibrations. Like industry SLA machines and for quick post-processing, I created a quick-release print surface



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.

Also, I needed to make the housing out of photopolymer resin since PLA is water-permeable

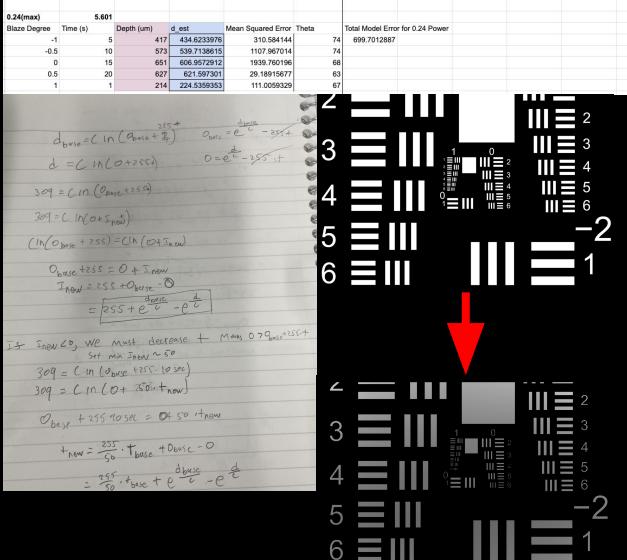


Micro/Millifluidic Channel
Various Print Conditions

Energy Density (mW/cm²)						d = C * ln((I+I₀)/E₀)						
0.18 0.993 Equal Time			Varied Time			d = C * ln(I/I₀) + A			C & A are material properties			
Blaze Degree	Time (s)	Depth (um)	Mean Squared Error	Time	d_measured ln Theta	C Value	A Value	d_ext	Mean Squared Error	d (um)	E₀ (mJ/cm²)	
-0.5	20	340	2301.701869	1.31	49	107.5813604	204.1953043	41.75453748	62.49677396	130.321	389.9700505	
0	20	409	371.1586721	5.49	311	66.2	75.7935385	311.0135229	327.3981635	268.8997053	130.321	0
0.5	20	449	1268.266684	10.00	442	77.4	10.09886529	436.0160217	448.8799559	44.8218102	130.321	0
1	20	413	104.6712821	20.00	414	73.1	413	423.308984	85.20948531	272.234701	130.321	0
				26.67	410	69.6	253.541667	13.22989754	426.4995364	Negligible	389.4913708	
Total Model Error for 0.18 Power 742.062228												

0.2 Time 2.13						d = C * ln((I+I₀)/E₀)						
Blaze Degree	Time (s)	Depth (um)	d_ext	Mean Squared Error	Theta	Time	d_measured	A (J/um²)	d, measure	E₀ (mJ/cm²)		
-0.5	5	301	359.1840161	86.98603521	76	1.31	49	107.5813604	41.75453748	130.321	389.9700505	
0	10	464	439.1020693	835.1770941	76	5.49	311	66.2	75.7935385	268.8997053	130.321	0
0.5	15	540	518.1409833	477.8306204	73	10.00	442	77.4	10.09886529	448.8799559	130.321	24.8217232
1	20	537	505.7648756	975.6329953	65	20.00	414	73.1	413	423.308984	85.20948531	413
	1	81	98.53857252	307.601526	—	26.67	410	69.6	253.541667	13.22989754	272.234701	0
Total Model Error for 0.20 Power 532.8497043												

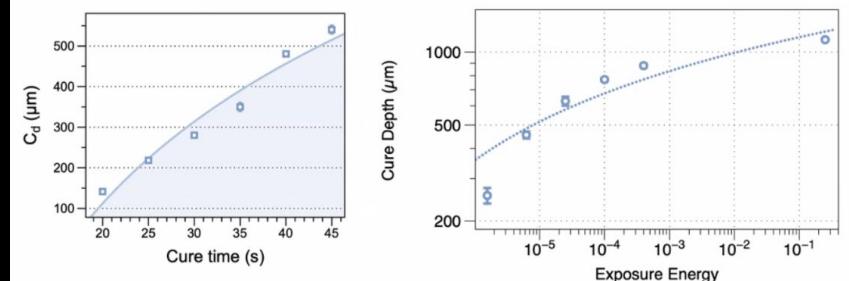
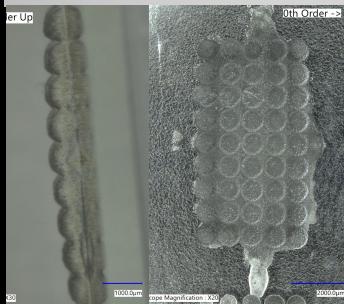
0.22 3.598						d = C * ln((I+I₀)/E₀)						
Blaze Degree	Time (s)	Depth (um)	d_ext	Mean Squared Error	Theta	Time	d_measured	A (J/um²)	d, measure	E₀ (mJ/cm²)		
-1	5	347	357.15360796	86.98603521	69	1.31	49	107.5813604	41.75453748	130.321	389.9700505	
-0.5	10	511	489.7444452	451.7054514	74	5.49	311	66.2	75.7935385	268.8997053	130.321	0
0	15	582	563.2093311	353.1005134	65	10.00	442	77.4	10.09886529	448.8799559	130.321	24.8217232
0.5	20	568	567.4839639	0.2662933023	64	20.00	414	73.1	413	423.308984	85.20948531	413
1	1	166	166.860159	0.7398730506	81	26.67	410	69.6	253.541667	13.22989754	272.234701	0
Total Model Error for 0.22 Power 342.849034												



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.



```

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.get())).pack()

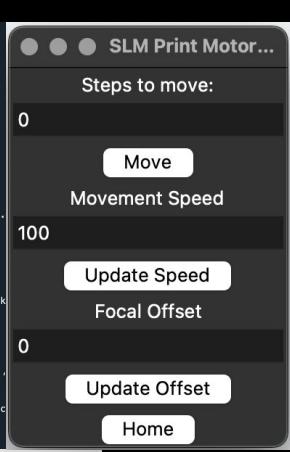
# Set Speed
tk.Label(root, text="Movement Speed").pack()
entrySpeed = tk.Entry(root)
entrySpeed.insert(0, "100")
entrySpeed.pack()
tk.Button(root, text="Update Speed", command=lambda: send_command('s' + entrySpeed.get())).pack()

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

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

root.mainloop()

```

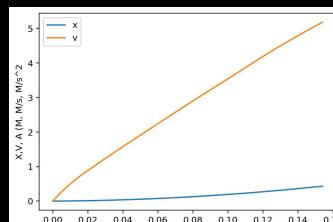


Motor Control GUI

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

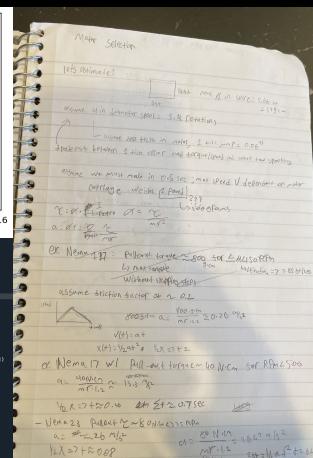


```

main()
{
    int i, j, k;
    float x[10][10], y[10][10], z[10][10];
    float sum;
    cout << "Enter matrix A" << endl;
    for(i=0; i<10; i++)
        for(j=0; j<10; j++)
            cin >> x[i][j];
    cout << "Enter matrix B" << endl;
    for(i=0; i<10; i++)
        for(j=0; j<10; j++)
            cin >> y[i][j];
    cout << "Matrix C = A + B" << endl;
    for(i=0; i<10; i++)
        for(j=0; j<10; j++)
            z[i][j] = x[i][j] + y[i][j];
    cout << "Matrix C = " << endl;
    for(i=0; i<10; i++)
        for(j=0; j<10; j++)
            cout << z[i][j] << " ";
}

Time (Sec)

```



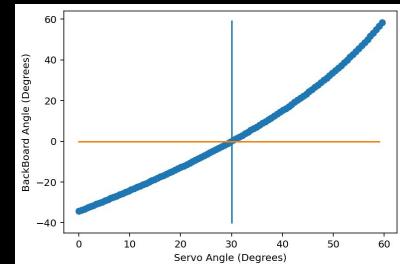
Motor Simulation for Motor Selection

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 algorithm, 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.



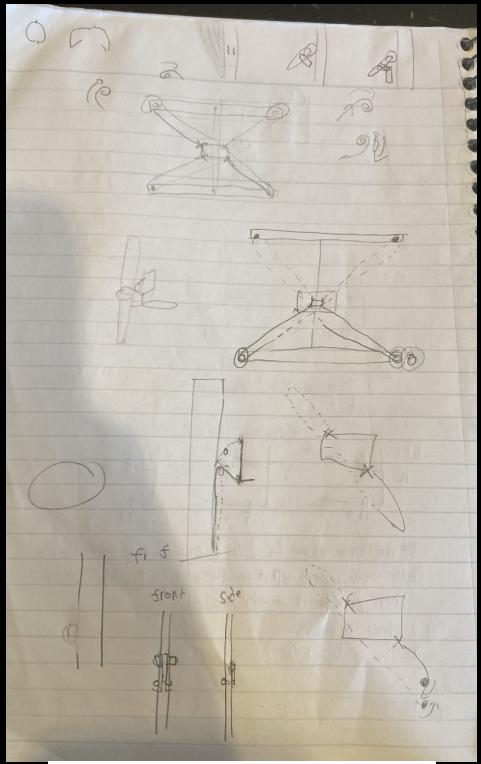
Backboard Servo to θ Relation



Cable-driven Carriage 1st Design



Rail System 1st Design



Some Design Sketches & Brainstorming

Homework cont.

$$\ddot{J} = \ddot{x}_h h_x + \ddot{y}_h h_y + \ddot{x}_M h_x^2 + 2\ddot{x}_M h_x \dot{y}_h + \ddot{y}_M h_y^2$$

$$\ddot{J}_{xx} = \frac{\partial}{\partial x} \left(\frac{\partial \ddot{J}}{\partial x} \right) = \begin{bmatrix} -\frac{3y}{q_1^2} & \frac{2y^2}{q_1^2} \\ \frac{2y^2}{q_1^2} & \frac{3(x+y)^2}{q_1^2} \end{bmatrix}$$

$$\ddot{J}_{xy} = \frac{\partial}{\partial x} \left(\frac{\partial \ddot{J}}{\partial y} \right) = \begin{bmatrix} -y^2 + x^2 y & 2xy^2 - x^3 \\ \frac{2y^2}{q_2^2} & \frac{d-x^2}{q_2^2} \end{bmatrix}$$

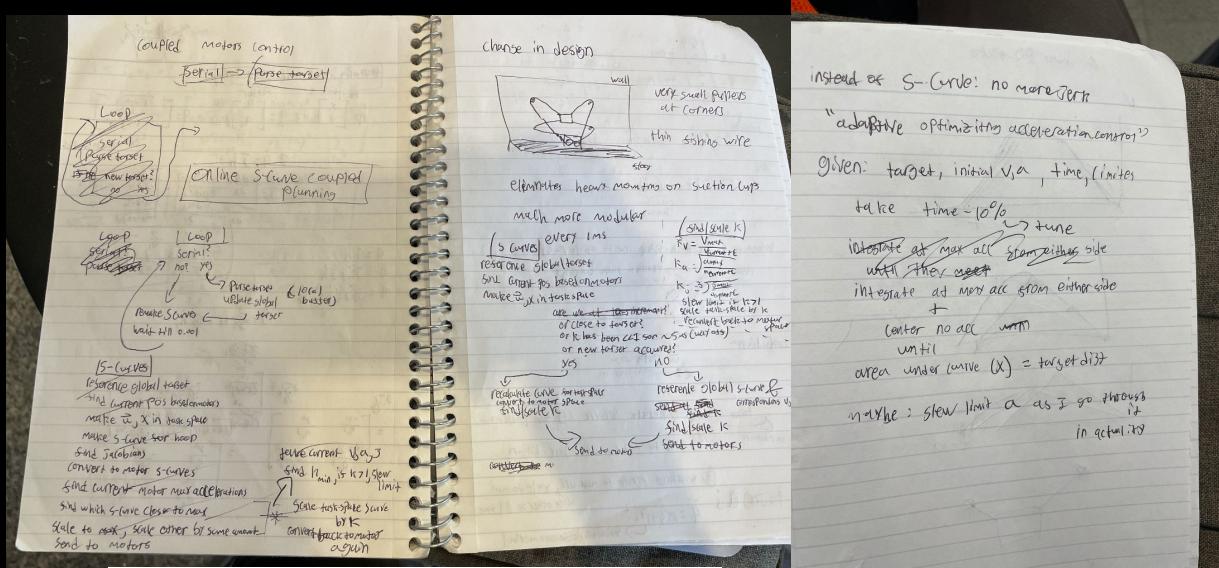
$$\ddot{J}_{yy} = \frac{\partial}{\partial y} \left(\frac{\partial \ddot{J}}{\partial x} \right) = \begin{bmatrix} xy^2 - x^3 & -3x^2 y \\ \frac{d-x^2}{q_2^2} & \frac{-3(x+y)^2}{q_2^2} \end{bmatrix}$$

person in metric scale \rightarrow meters
 robot
 $J = \begin{bmatrix} q_1 & q_2 \\ q_3 & q_4 \end{bmatrix}$
 $q = \begin{bmatrix} \frac{J_{11}}{J_{11}+J_{22}} & \frac{J_{12}}{J_{11}+J_{22}} \\ \frac{J_{21}}{J_{11}+J_{22}} & \frac{J_{22}}{J_{11}+J_{22}} \end{bmatrix}$
 $\dot{q} = \begin{bmatrix} \frac{\dot{J}_{11}}{J_{11}+J_{22}} & \frac{\dot{J}_{12}}{J_{11}+J_{22}} \\ \frac{\dot{J}_{21}}{J_{11}+J_{22}} & \frac{\dot{J}_{22}}{J_{11}+J_{22}} \end{bmatrix}$
 $\ddot{q} = \begin{bmatrix} \frac{\ddot{J}_{11}}{(J_{11}+J_{22})^2} & \frac{\ddot{J}_{12}}{(J_{11}+J_{22})^2} \\ \frac{\ddot{J}_{21}}{(J_{11}+J_{22})^2} & \frac{\ddot{J}_{22}}{(J_{11}+J_{22})^2} \end{bmatrix}$

Jacobian Transformations from Carriage Frame to Motor Frame

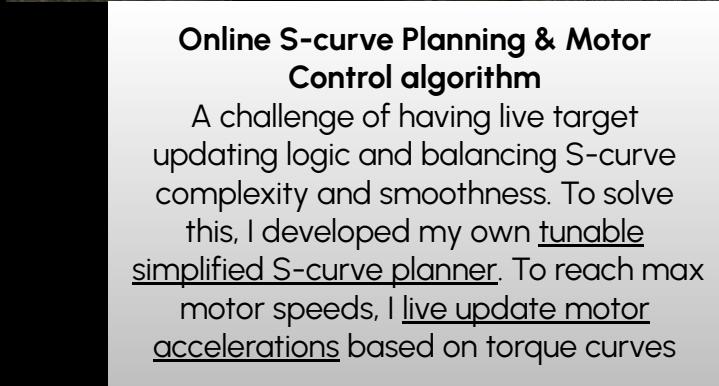


OpenCV Position and Velocity tracking



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 tunable simplified S-curve planner. To reach max motor speeds, I live update motor accelerations based on torque curves



Kuriosity Robotics



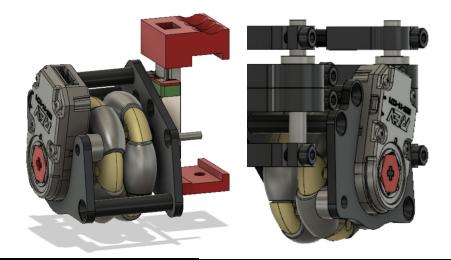
Main Takeaways:

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



Ball & Cube Intake

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

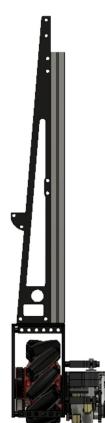


Odometry Pods

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

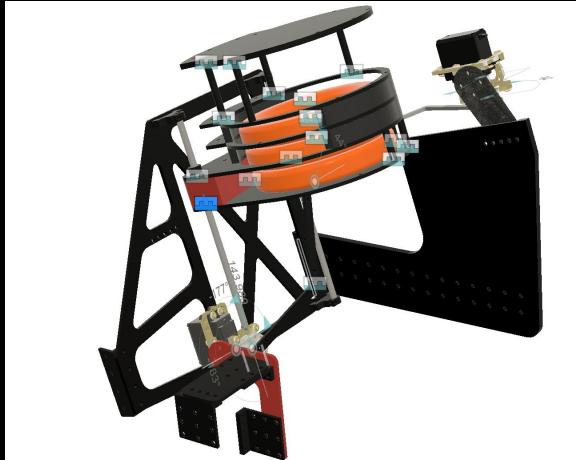


Our last 3 robots



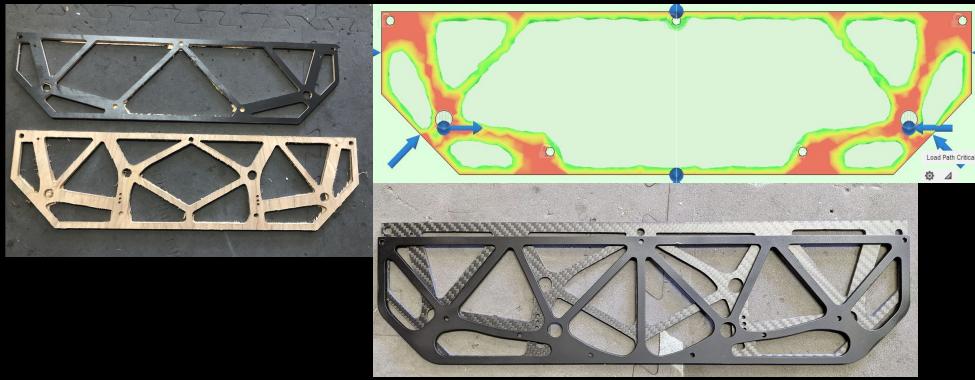
Linear Slide System

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



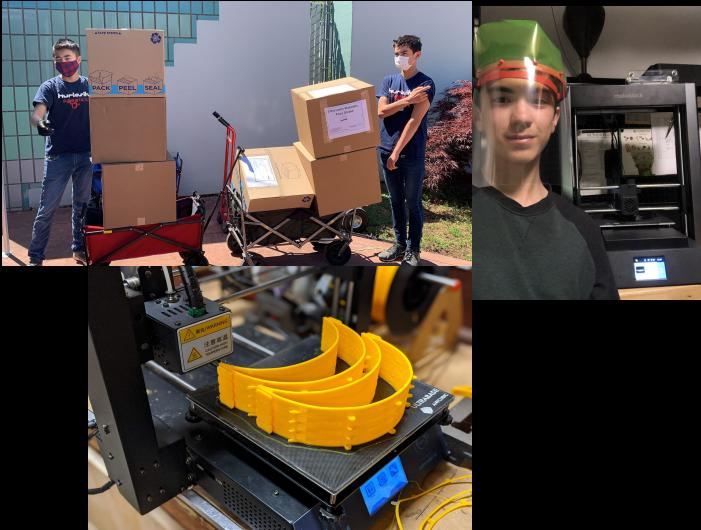
Hopper Transfer

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



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

G Structure

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

- CNC cut plates
- 3d printed parts
- 3d printed brackets
- adhesives/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 that 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 a pre-programmed path. CNC cut aluminum plates are by far the most common way to make structural parts because they're simple and easy to make and use. When plates are flat or rectangular, plates can make lightweight but rigid 3d structures.

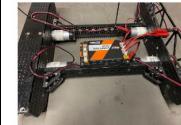
The CNC can also cut other materials, like wood, Delrin (aka acetal or POM), or polycarbonate, but we only use those for specialty purposes like aesthetic side panels, lightweight arms, or flexible parts.



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 parts (a lot of panels).

Channels

Channels are large structural parts from Gobildia. 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 Gobildia channel. Also available with taller side walls.

We don't use channels very often, as it is normally easier to use CNC-cut 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 complex brackets.

Another similar piece we sometimes use is 1" aluminum box beam. We used this for our top bar in the 2019-20 (skyrone) season. It was useful because of its strength, simplicity, and most of all, low weight. Because of its profile, it could achieve high strength without thick walls, so 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 drivetrain robot lighter.

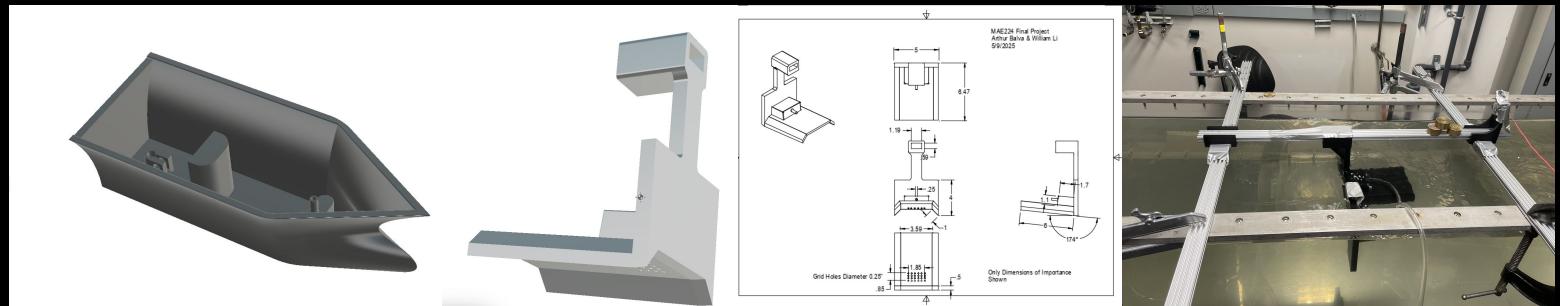
3d printed parts

We use our 3d printers for everything that can't be bought or manufactured another way. 3d printing offers amazing flexibility; you can print anything pretty easily. 3d prints can be made from a wide variety of materials, each with their own characteristics and cost concerns. The general idea is that 3d printing is strong; 3d printed parts are not as strong as 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. However, 3d printing is great in a few areas: it's a much faster range of prototyping (less time, less effort and learning), so 3d printed parts are generally stiffer and less shock-resistant than other materials like polycarbonate or polycarbonate. We might, however, have to print in polycarbonate for the 2022-23 season (Power Play), so that we can have PP parts on our PP robot. Sorry. I'm so sorry.

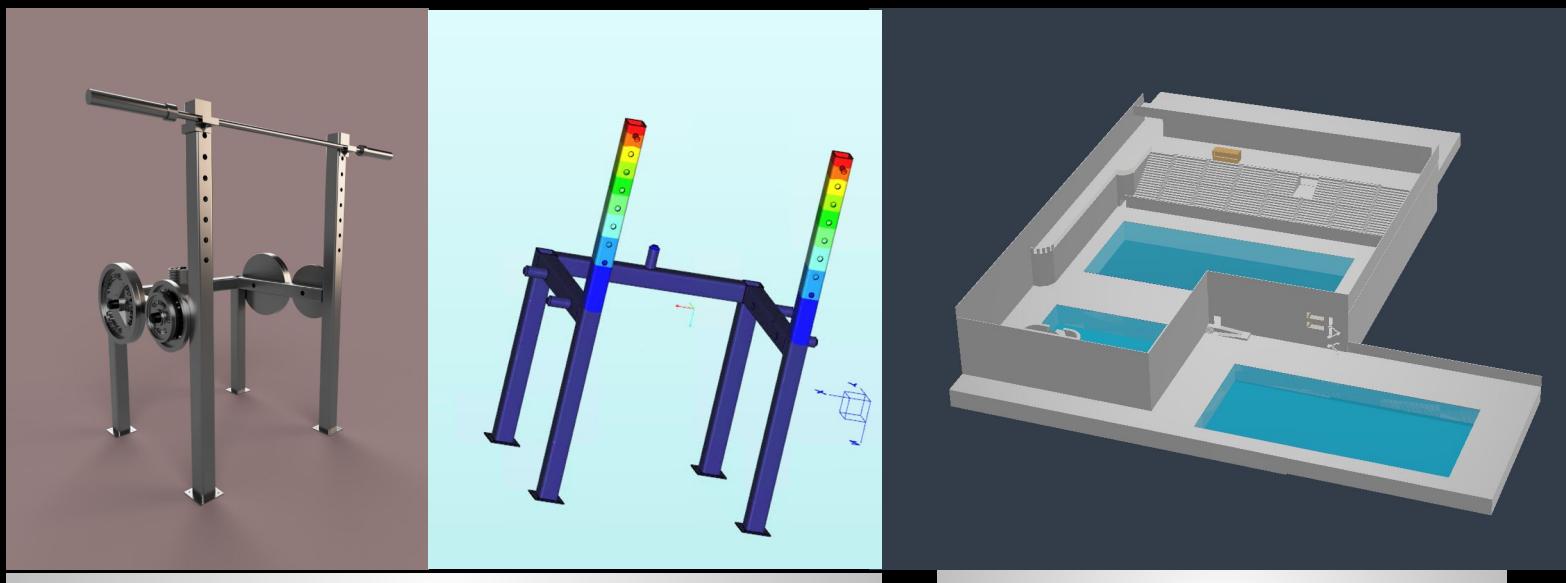
Here are some examples of 3d printed parts:

Sample of Hardware Documentation I did as Lead

Miscellaneous

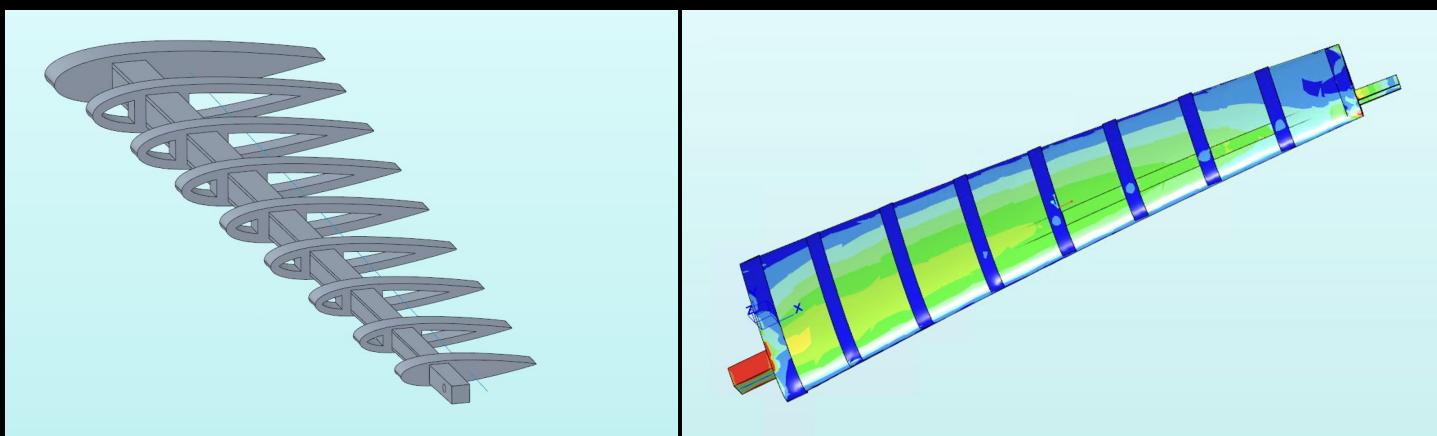


Boat Models to analyze Air Cavity Systems for open-ended Class Project
Flat Sided iteration created to create readable force outputs with flow limitations
of the channel



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