FPV Quadcopter Drone Concept (Design & Analysis)

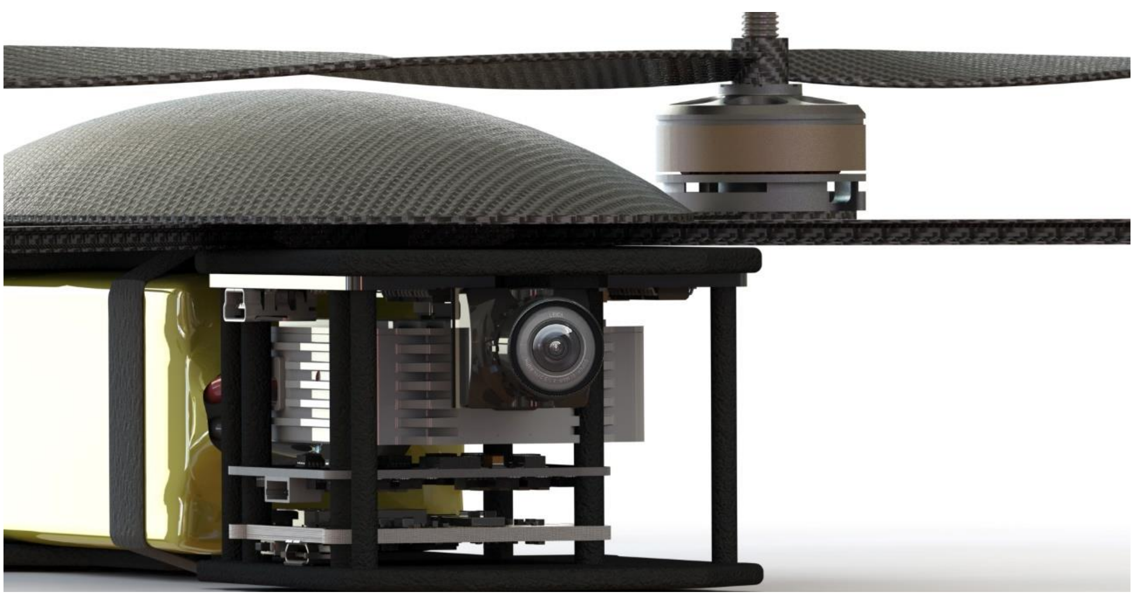
Sept 2021

Goal: To design a First-Person View (FPV) Quadcopter Drone that would be able to fly for an extended period of time by combining a very low weight with a large battery and powerful motors.

The FPV Drone Concept was designed in SOLIDWORKS with solid modeling and using models of real drone components. The design of the frame was done by studying multiple drone kits and taking general engineering principles that help to reduce weight without significant losses in structural rigidity. One thing I also needed to do was to pick the right components for this drone to ensure it could achieve the weight, cost, and performance I had intended for it to. This meant research for different Batteries, Electronic Speed Controllers (ESC), and other electronic components.

Challenges & Solutions:

- **Bending Stress –** The main goal of this project was to keep the weight of the drone very low. For this reason, the arms that carry the motors are very thin which makes them susceptible to failure from bending. This is a classical cantilever beam problem with the motors pulling the ends of the arms up and the weight of the battery and electronics pulling the other ends of the arms down. To deal with this, the cross section of the arms are I-beams, and they are made of carbon fiber which is a very stiff material so there will be less yielding and the strength of the material will help to support the weight.
- **Weight Distribution –** Due to the focus on having a long flight time, the battery for the drone is very large and heavy compared the weight of the frame and motors. The current position of the battery means the rear motors will have to work harder and in the case of a loss of power, the drone will fall backwards. The solution for this would be to increase thrust in the rear by changing the propellers. The battery is a lithium polymer battery which have a high energy density, but it will still fall backwards. This is actually preferable since the costs of electronics is higher than the battery.



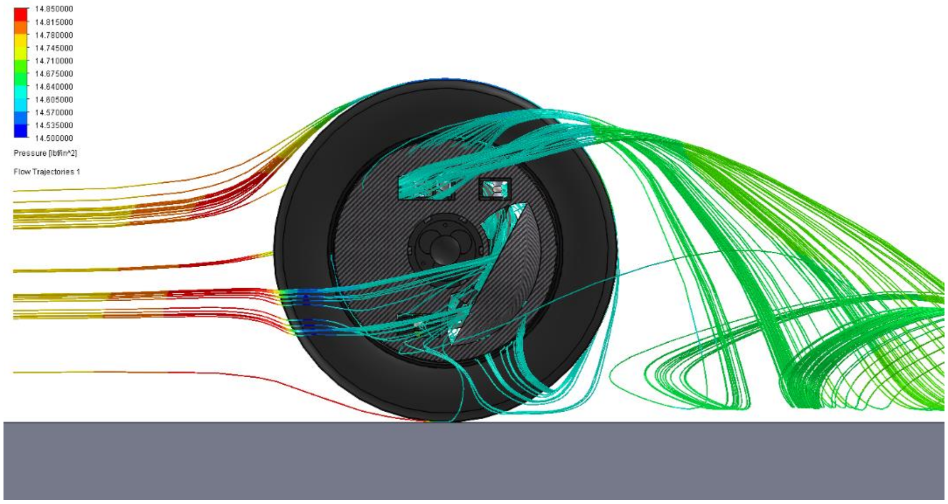
Lessons Learned & Future: I've always been interested in drones and so I thought it'd be cool to design one for myself. One thing I noticed was that most of them had relatively small batteries so couldn't fly for very long time. One of my main takeaways from this was designing by using off the shelf components. In the future, I'm looking forward to further refining the design and building it

Note: The top dome doesn't really serve a functional purpose.

Formula SAE – Carbon Fiber Brake Ducts (Design & Analysis)

Jan 2021 – Feb 2021

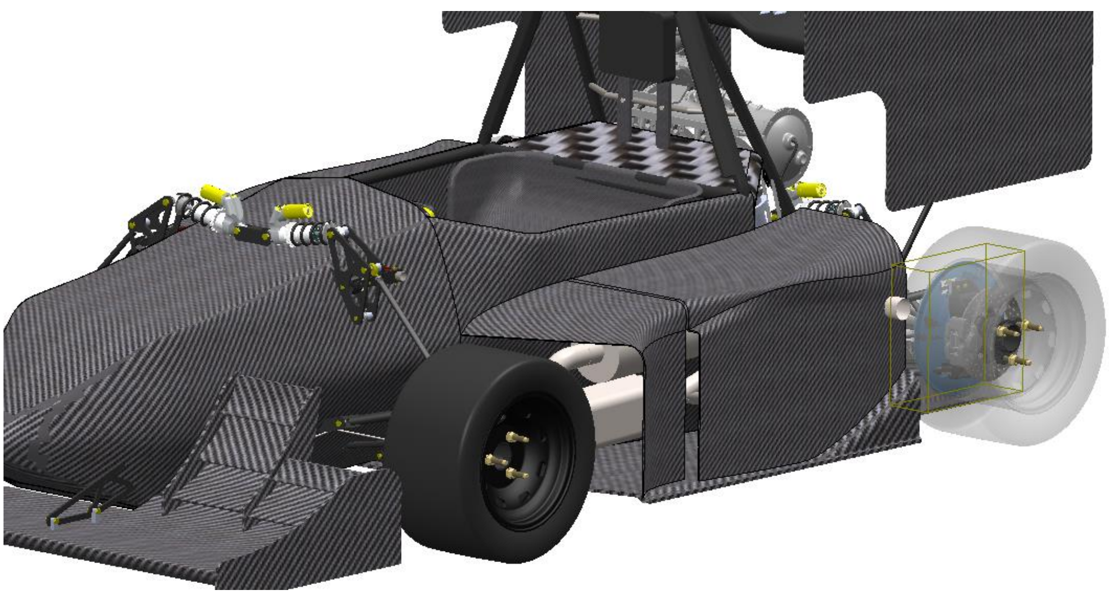
<u>Goal:</u> To reduce the size of both the front and rear brake rotors which will reduce the unsprung weight of the vehicle without significantly reducing the vehicles braking performance.



The Brake Duct was designed in SOLIDWORKS through a combination of solid and surface modeling. Interactions between the wheel and Brake Duct is a safety risk so stresses at maximum speeds to determine the deflection of the brake duct near the wheels using Finite Element Analysis (FEA). Although it has not been manufactured with final material because of virtual setting, carbon fiber was chosen to be material for low weight and high stiffness. Manufacturing process was chosen to be a vacuum sealed molding process creating the mold from a high-fidelity resin SLA printer.

<u>Challenges & Solutions:</u>

- **Suspension Geometry Travel –** Determined the maximum angles for both the upper and lower control arm and accounted for the movement of the steering arm for the steering arm.
- **Brake Rotor Reduction –** Braking performance only decreases when the brake pads have reached a temperature threshold in which the brake pads produce a gas that prevents them from generating sufficient friction to cause the vehicle to slow down. Reducing the brake rotor decreases the time until the brake system has until brake fade so Computational Fluid Dynamics (CFD) was performed to determine how much air could be redirected into the wheel to counteract the reduction in brake rotor size.
- **Drag –** The introduction of the brake duct increases drag so the design needed to ensure the reduction of vehicle's unsprung weight would still be beneficial considering the increase in drag. The most efficient design was chosen through simple interpolation of extremities in drag and brake size then adapted to what was available commercially.



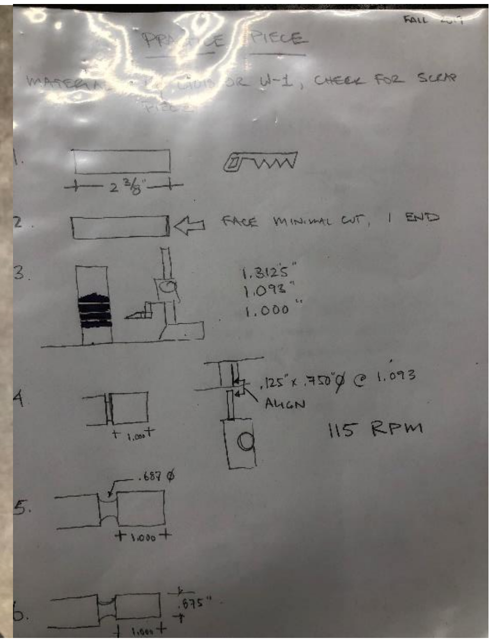
<u>Lessons Learned & Future:</u> I really enjoyed working on this. This project really showed me how different aspects of my degree come together and I loved using different tools like CAD, FEA, CFD, and Thermal simulations to help prove that my design was effective. Things to look forward to in the future is real world testing to verify my results.

Steel Ball Peen Hammer (Manufacturing)

Sept 2019 – Dec 2019

Goal: To manufacture a ball peen hammer using a variety of different machining processes given a set within a tolerance of .05" and to harden the hammer through a heat treatment process.





The project started with nearly a foot of 1" diameter untreated steel rod cut with a horizontal band saw from ~20ft long rod. I first created my cutting bit and 60° bit for the lathe using a bench grinder and water to prevent the bits from overheating. Some of the machining techniques used on the lathe were facing, tapering, chamfering, drilling, cutoff, boring, drilling, and threading.

Challenges & Solution:

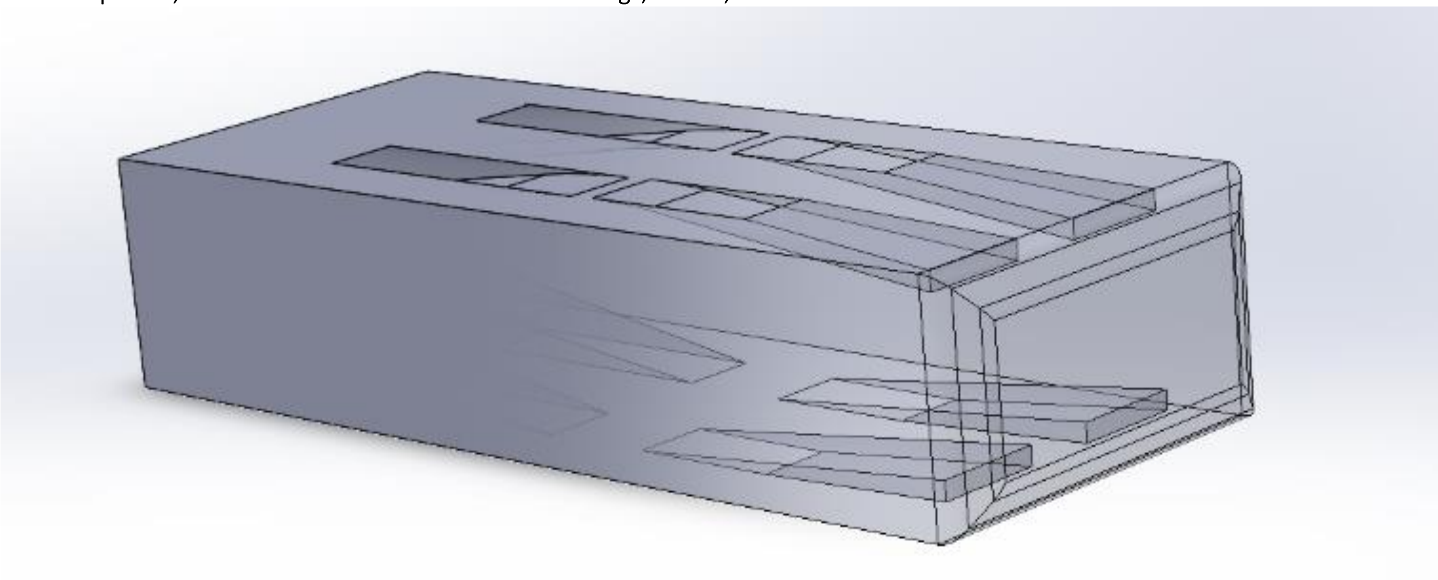
- **Heat Treatment:** Since this is a tool that undergoes a lot of stress, the hammer needed to be hard but not brittle. Oil quenching was chosen largely because it is what I had access to, but it was advantageous because there's a greater severity compared to most gases or molten salts. It also is not too aggressive which would increase the likelihood of cracks forming.

Lessons Learned & Future: This was my first major experience with machining and converting raw materials to usable objects. Doing this taught me about how my designs will be manufactured and so now Design for Manufacturability (DFM) is something I am consistently thinking about during my design process. Additionally, this exposed me to the different manufacturing processes so I'm planning on doing some future projects involving casting and molding.

USB B Port Replacement (Design & Additive Manufacturing)

Jan 2021

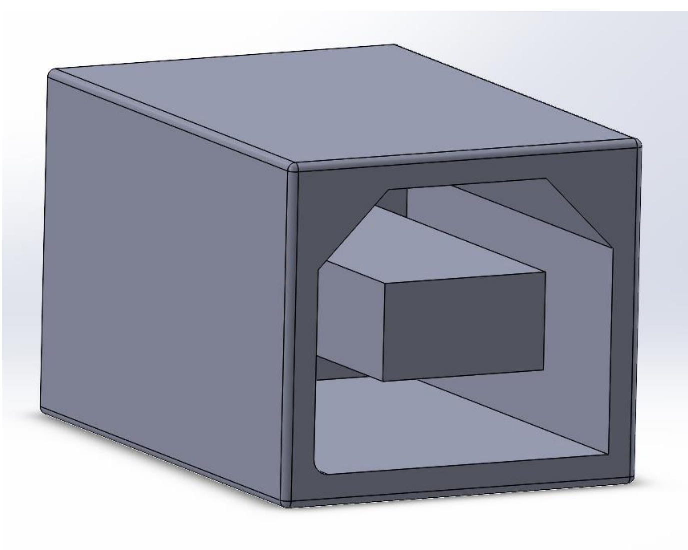
<u>Goal:</u> This was a weekend project where I needed to create the interior guide for a Blue Snowball Microphone's USB Type B Female Port and print it, so I'd be able to use it for virtual meetings, school, and events.



The process for created this included getting the dimensions for the internal USB Type B guide for the pins. A caliber was used to measure the width and height of the four data/power/ground pins so I could ensure they would fit into the holes I created. This would be attached using adhesive since the bonding was between two plastics. After the design was finalized, it was imported to Cura where it could be converted to G-code and printed using my Creality Ender 3 FDM Printer in Polylactic Acid (PLA).

<u>Challenges & Solution:</u>

- **Tolerances:** The size of this component being relatively small meant that tolerances would be tight, especially given my 3d printer is a budget printer. I decided to pursue a clearance fit because the pins themselves would help to keep the male cable from falling out and my personal printer tends to print slightly oversized. These factors meant it would likely not fit or have a very tight fit. After printing, I found it slid in smoothly, but it was still tighter than necessary which caused it to pull the part I made out of the female port.

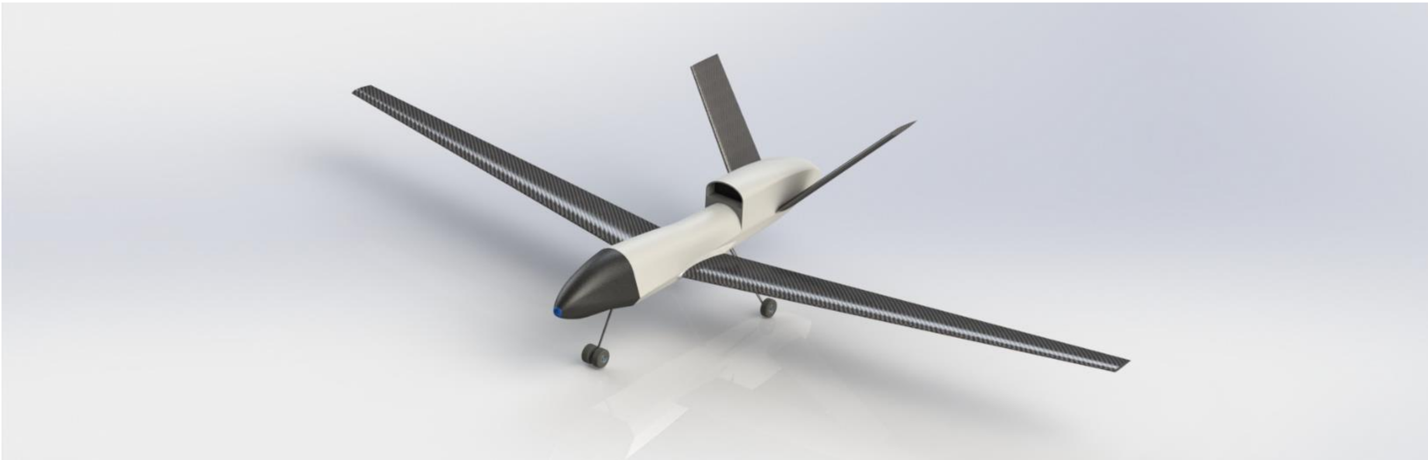


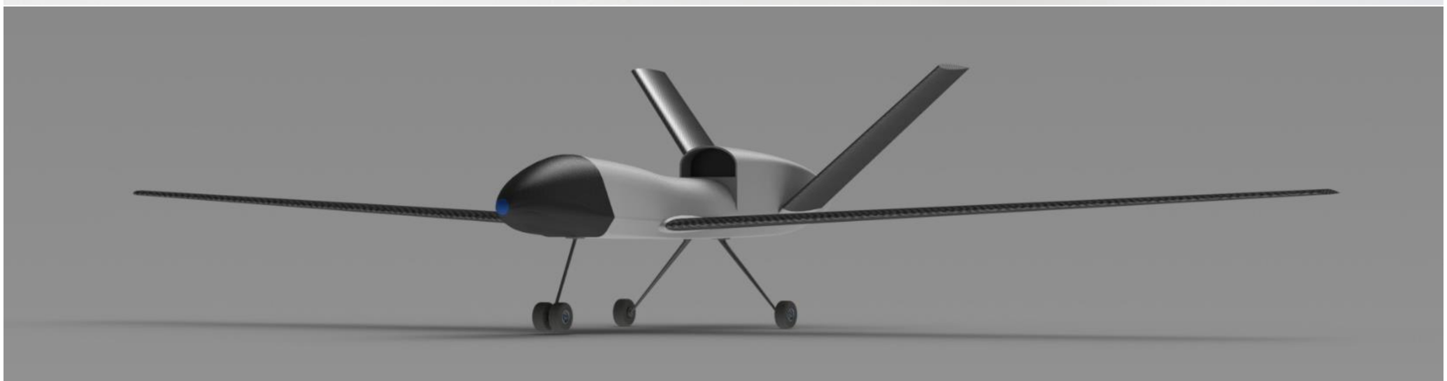
<u>Lessons Learned & Future:</u> The quick process made this project very interesting because I wanted to finish this by the time my school started on Monday. If I had more time, I would reduce my size by a little bit more and add a backplate for the adhesive to give the port more area to hold onto the backside of the port.

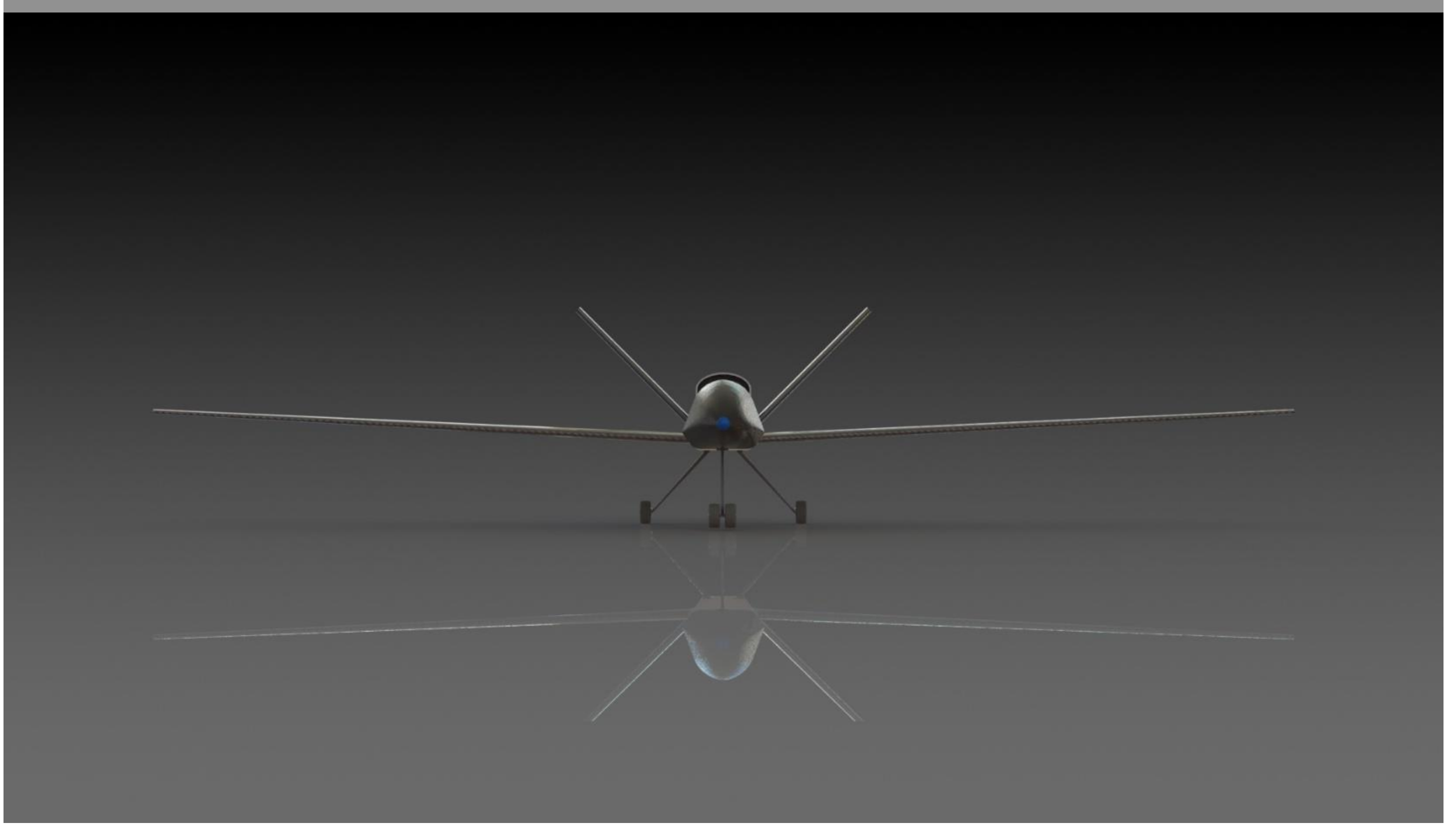
Autonomous Plane Design Concept (Design & Analysis)

Oct 2021 – Present (link)

Goal: Drone that could perform autonomous fixed wing aircraft that can perform various mission with different sensing payloads







Still in a work in progress: here's a link to the project

Autonomous Miniature Boat (Testing & Design Iteration)

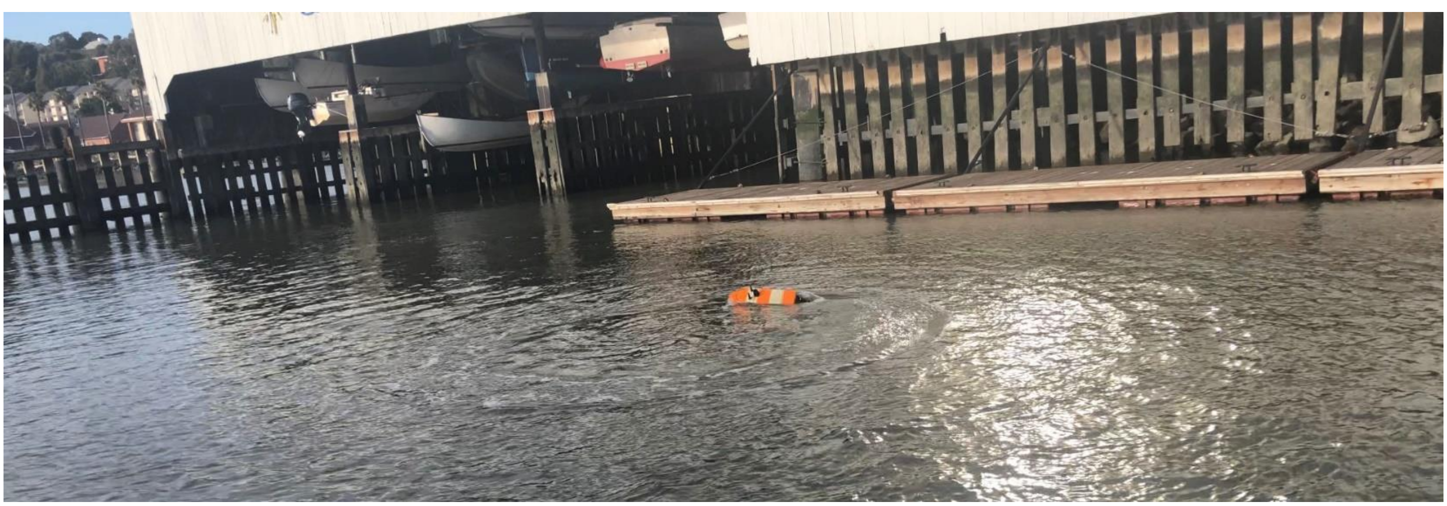
Sept 2018 – Apr 2020

Goal: This project was very mature when I joined it with one of my Mechanical Engineering professors, so I was involved testing and iterating on the design of the vessel.

The process for testing included operating the vessel and monitoring both the boat physically to make sure it was running smoothly and the sensors (GPS, Compass, Gyroscope, Accelerometer) through Ardupilot. After collecting data and taking notes about how the vessel performed, I could then find ways to improve the design and test my designs with more testing.

Challenges & Solution:

- **Variable Water Conditions:** By far the most challenging part of this was the variable weather conditions. From a design aspect, designing to improve condition sometimes hindered in the performance of another condition. For example, turning with high currents was sometimes difficult in certain directions. One of the solutions to solve this was to increase the rudder size. This would increase the turning radius even in rougher water conditions, but it increased the likelihood of seaweed getting tangled in the rudder and immobilizing the vessel. Multiple rudder designs were created which could be swapped depending on the water conditions.



Lessons Learned & Future: My next step would be to recreate this project myself using my own original design for everything. I've already modeled the hull based off a coast guard boat with a self-righting design by creating a very low center of gravity. This is because the wave size relative to the vessel size makes it dangerous to operate in many water conditions and even with waterproofing, some sensors like GPS don't work if the boat was capsized.

Mechanical Ice Cream Scoop (Analysis)

Sept 2020

Goal: The goal for this project was to perform a set of static analysis on an everyday mechanical device and compare the theoretical results with experimental results. Specifically, I calculated the amount of force required to get the thumb lever to begin to move.

Rate Per 360 degrees = Ed^4 / 10.8DN

E Modulus of Elasticity = 28 Mpsi (Stainless Steel)
d wire size = 0.100”
D Mean Diameter = 0.500”
N Number of active coils = 4

Rate Per 360 degrees = ((28*(10^6))(.1^4))/((10.8)(.5)(4)) = 2800/21.6 = 129.630
Rate Per Degree = 129.630/360 = 0.3601

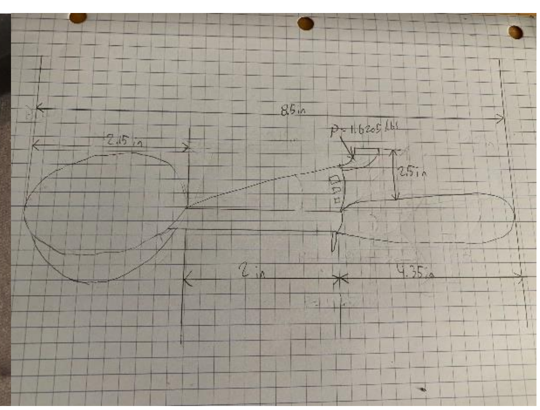
Load = Rate Per Degree * Distanced Travel
Load = 0.3601*45° = 16.2045 pounds

16.2045 lbs @ 0.25” = P
2.50”/0.25” = 10 so 16.2045 lbs/10 = 1.6205 pounds @ 2.50”
P = 1.6205 lbs

P is the required force to cause the thumb lever to move.

Challenges & Solution:

- **Material Selection:** The ice cream scoop I have access to came from Walmart and was bought a few years ago. There were no specifications I could find from the manufacturer regarding material or dimensions, so I needed to find these myself. I did research about the types of materials used in both residential cooking and industrial food processing to determine which material properties I should use in my calculations. I did not test them at the time but I’m able to say with a fair bit of confidence that the metal is some form of stainless steel. (Aluminum of this thickness would deform with the amount of force I used; very weak magnetism; no evidence of rust or corrosion in at least 3 years of use)
- **Oversimplification:** This experiment excluded many factors which would increase the amount of force required to move the thumb press. This includes the static friction the in between the small spur gear and first hole in the thumb press which converts linear motion relative to the gear to rotary motion in the gear/shaft combination. The second omission was the bending of the spring due to moments on end of the torsion spring. Lastly, I calculated angles, thickness, widths, and lengths with the iPhone Augmented Reality measuring app, a straight ruler, and by eye because I didn’t have access to calipers at the time.
- **Testing:** The challenges surrounding testing mainly focused on the limited household objects I had a few days after moving to a new apartment. Fortunately, this consisted of a set of 1lb, 3lbs, 5lbs, and 10lbs dumbbell weights I borrowed from my mom. When testing, I confirmed that 1lb was insufficient and 3lbs would make the thumb lever move.



Lessons Learned & Future: This project helped me to understand how engineering plays into products we use every day. It really demonstrates the scope of engineering and I was able to gain some experience with static analysis. With more time, I pursue account for both static friction and the bending of the end of the spring as well as possibly expanding this to a dynamic analysis.

5 Spoke Wheel (Design Process)

Mar 2021

<u>Goal:</u> This was a weekend project was to learn about some of the design techniques that go into producing commercial products. For this, I followed a 4-hr long tutorial going over the design process which gave me insight into how this company designed this product.

Here is a model I created of the VOSSEN VPS-303 5 spoke wheel. This was purely a learning exercise for me and even thought it was a carbon copy of the original design, I believe doing this helps me to become a stronger mechanical engineer. The process for this included me learning new techniques regarding solid and surface modeling along with some best practices this company uses which I can incorporate into my own designs. Even though I was following this tutorial, I still needed to make some changes regarding my design because their version of SOLIDWORKS was different than mine, so I needed to come up with my own ideas.

<u>Lessons Learned & Future:</u> I plan on doing my own custom design soon to see what I've learned. Even though my choices would be based off appearance, I could incorporate stress analysis to determine if my design were better in certain areas compared to the original design.

<u>Note:</u> The speck at the bottom of the when is for the tire inflation stud. It's not a rendering error or mistake in the design.

Thank you for looking at my portfolio.

Have a nice day!