DEPARTMENT OF
MECHANICAL ENGINEERING

TEAM 24

THE GOOSE

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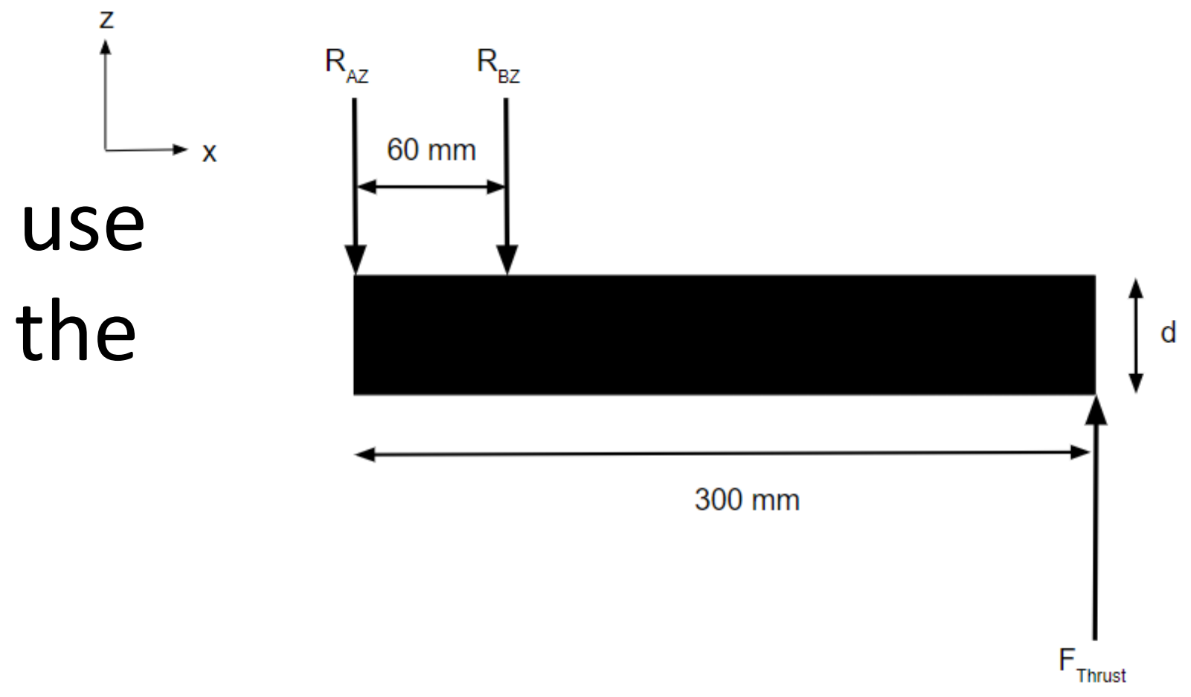
Problem Definition

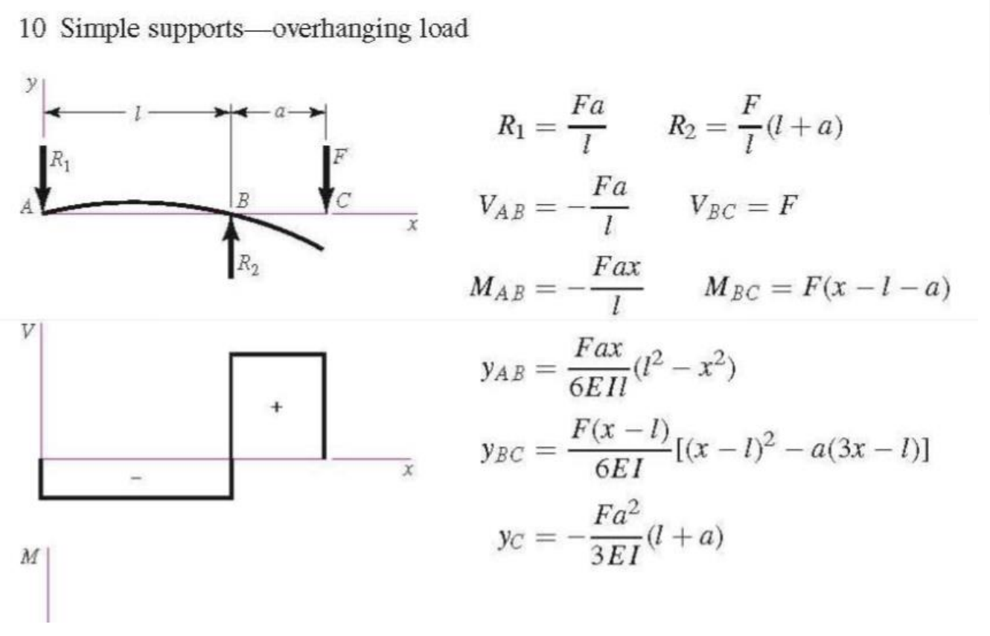
It's a bird! It's a plane! No, it's a duck… or maybe a fish? If you blink, you might mistake this flying, swimming contraption for an everyday animal, but you are really witnessing ME Team 24's aerial-aquatic quadrotor: The Goose. This design came to life in response to limitations in underwater reconnaissance caused by underwater travel speed. Modern underwater ROV's travel at speeds below 3 knots while aerial drones can travel at over 5 times that speed. Having the ability to travel in air and sea would allow a drone to survey different underwater locations in an efficient manner. Existing methods for overseeing water ecosystems are not optimal due to limited coverage, slow data collection, and high costs. An aerial aquatic drone can offer a more effective and versatile platform for collecting real-time data, surveilling the environment, and managing resources in aquatic ecosystems.

Design Calculations & Analysis

Drone Arm Diameter Sizing:

- Excessive deflections or vibrations in our drone arms would disrupt sensor readings for our control system and could result in catastrophic failure. Thus, we had to design our rods with a maximum deflection of 0.5 mm to ensure stability.
- Modeling the arms as a simply supported beam with an overhanging load, we could use tabulated deflection formulae to solve for the minimum diameter of the rods:
- Calculated d: 9.5 mm; Actual d: 10 mm




10 Simple supports—overhanging load

$$R_1 = \frac{Fa}{l} \qquad R_2 = \frac{F}{l}(l+a)$$

$$V_{AB} = -\frac{Fa}{l} \qquad V_{BC} = F$$

$$M_{AB} = -\frac{Fax}{l} \qquad M_{BC} = F(x-l-a)$$

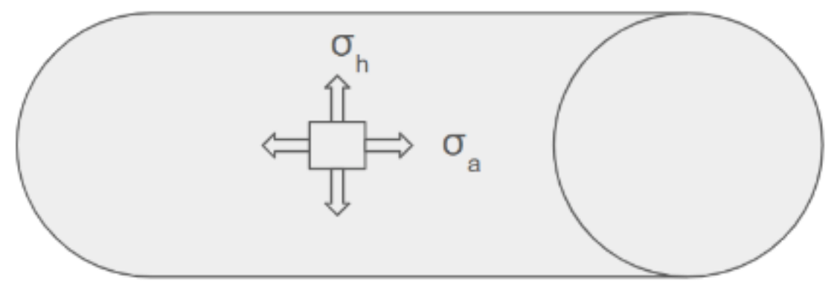
$$y_{AB} = \frac{Fax}{6EIl}(l^2 - x^2)$$

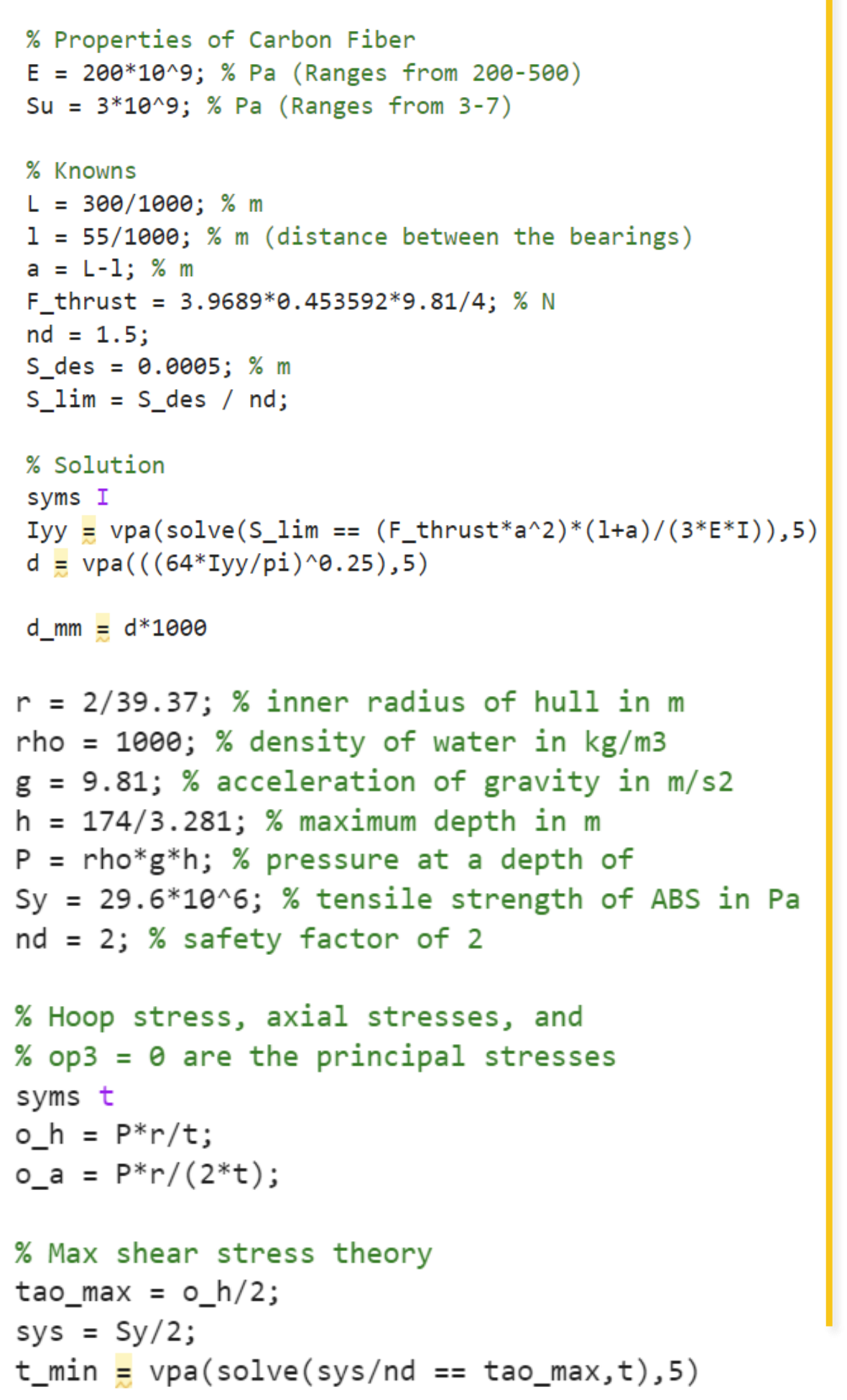
$$y_{BC} = \frac{F(x-l)}{6EI}[(x-l)^2 - a(3x-l)]$$

$$y_C = -\frac{Fa^2}{3EI}(l+a)$$

Electronics Hull Thickness Calculations:

- High pressure experienced by the drone underwater if signal is lost should not compromise the drone's electronics.
- We can design the hull to survive pressures at the bottom of the Chesapeake Bay modeling our hull as a thin-walled cylindrical pressure vessel.
- Calculated t: 1.7 mm; Actual t: 2 mm





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% Properties of Carbon Fiber
E = 200*10^9; % Pa (Ranges from 200-500)
Su = 3*10^9; % Pa (Ranges from 3-7)

% Knowns
L = 300/1000; % m
l = 55/1000; % m (distance between the bearings)
a = L-l; % m
F_thrust = 3.9689*0.453592*9.81/4; % N
nd = 1.5;
S_des = 0.0005; % m
S_lim = S_des / nd;

% Solution
syms I
Iyy = vpa(solve(S_lim == (F_thrust*a^2)*(l+a)/(3*E*I)),5)
d = vpa(((64*Iyy/pi)^0.25),5)

d_mm = d*1000
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```
r = 2/39.37; % inner radius of hull in m
rho = 1000; % density of water in kg/m3
g = 9.81; % acceleration of gravity in m/s2
h = 174/3.281; % maximum depth in m
P = rho*g*h; % pressure at a depth of
Sy = 29.6*10^6; % tensile strength of ABS in Pa
nd = 2; % safety factor of 2

% Hoop stress, axial stresses, and
% op3 = 0 are the principal stresses
syms t
o_h = P*r/t;
o_a = P*r/(2*t);

% Max shear stress theory
tao_max = o_h/2;
sys = Sy/2;
t_min = vpa(solve(sys/nd == tao_max,t),5)
```

Final Design

Design Description:

- Our aerial-aquatic quadrotor functions like an average drone in the air, and it uses a rotating arm design to propel itself within water.
- In the air, four motors, which alternate in their spin direction to balance torque and prevent the drone from rotating, spin 4 propellers to lift the drone upwards.
- In the water, the drone's arms will all rotate to the same angle and use thrust vectoring to navigate the underwater environment.

Servo Arm Design:

- As pictured to the right, a servo motor mounted to the bottom of the drone turns a geartrain to which all the drone arms are connected. Every other arm will rotate in the same direction. Using different power to each motor, the quadrotor can be thrusted in the desired direction underwater along all three axes.

Waterproof Hull:

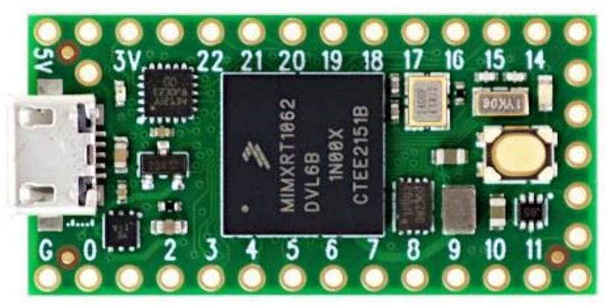
- Our waterproof hull consists of a 3D printed ABS frame with sealed holes for wires to reach the motors and two removeable, flexible endcaps with internal O-rings to seal the ends.

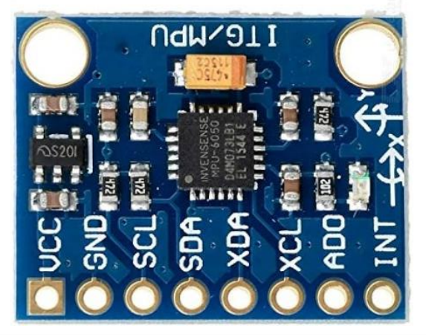
Motor Mounts:

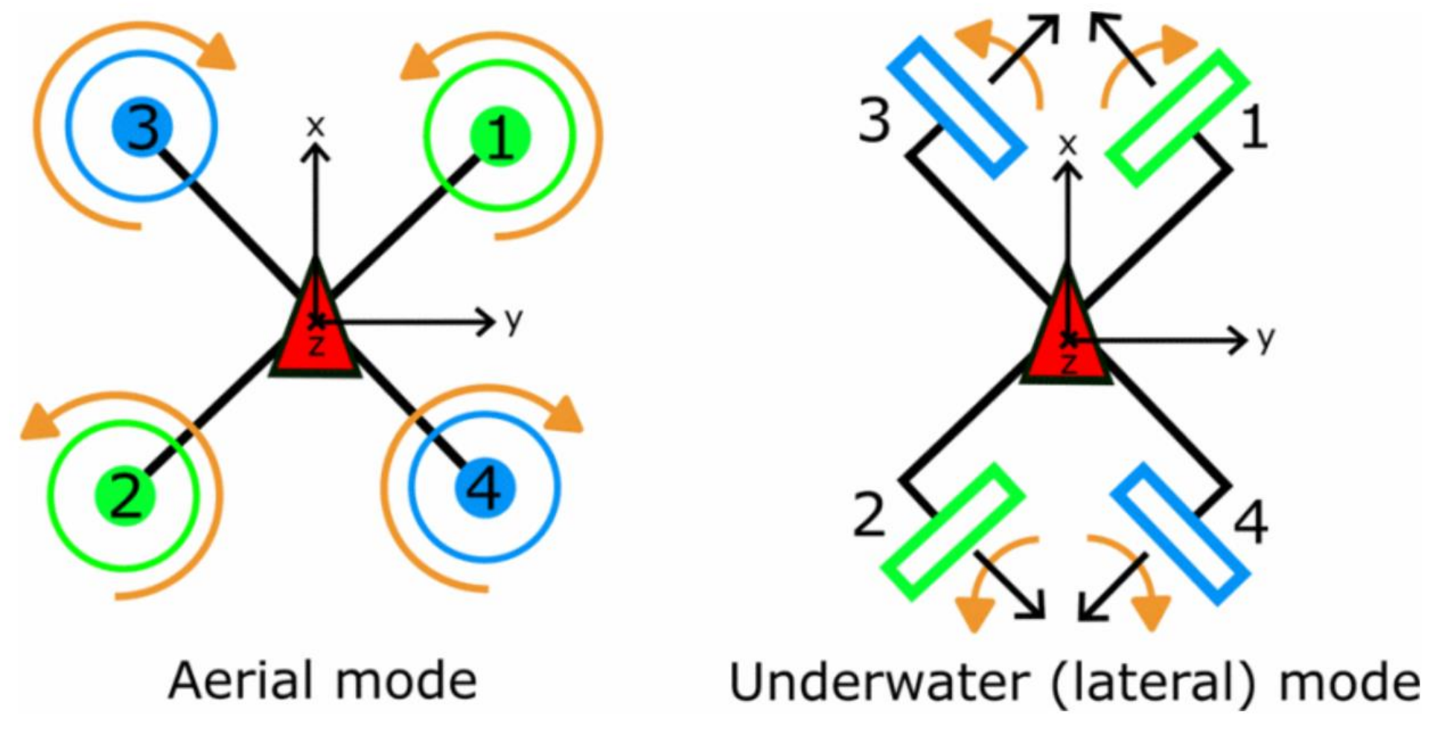
- Our 3D printed ABS motor mounts work by tightening the holes at the bottom to clamp tightly around each drone arm.

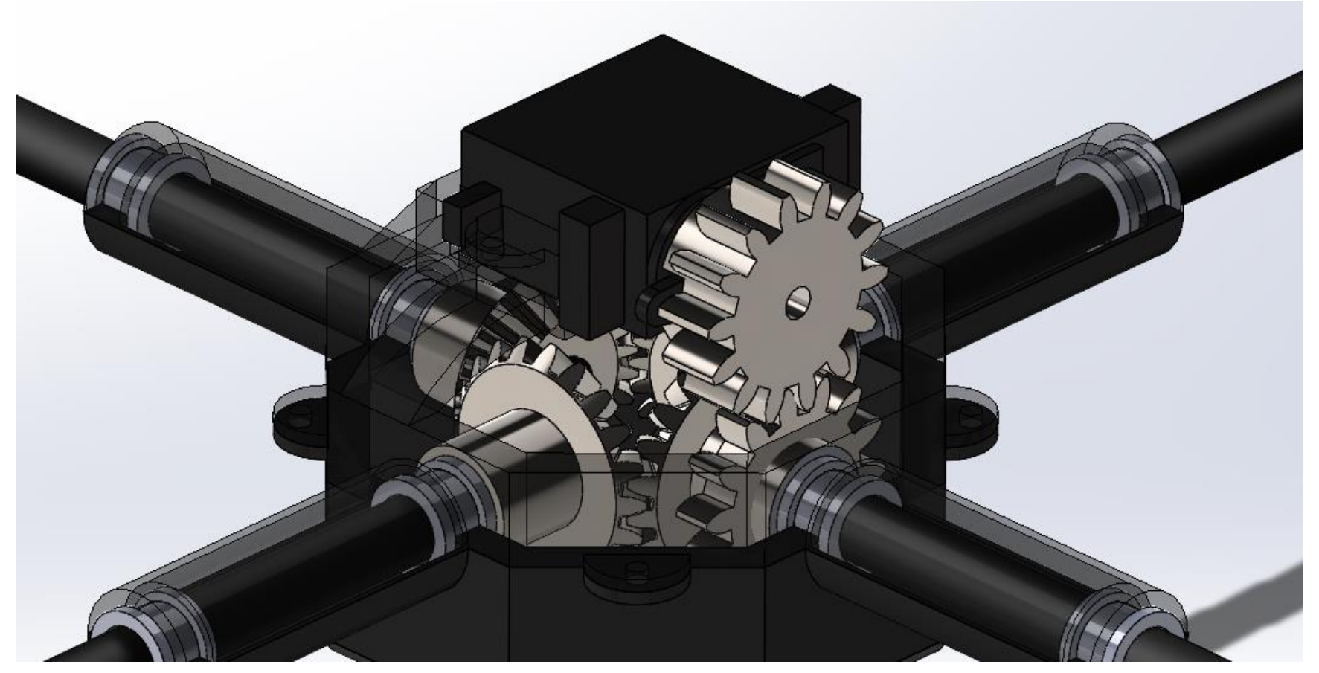
Electronics:

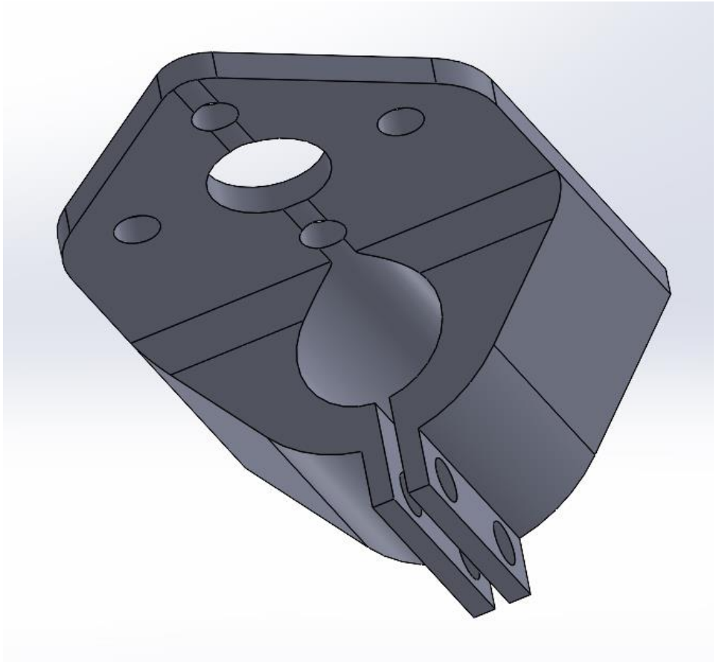
- Our flight control system consists of a 3S LiPo battery, MPU6050 IMU, FS-IA6B radio unit, and Teensy 4.0 integrated with modified dRehmFlight VTOL software.

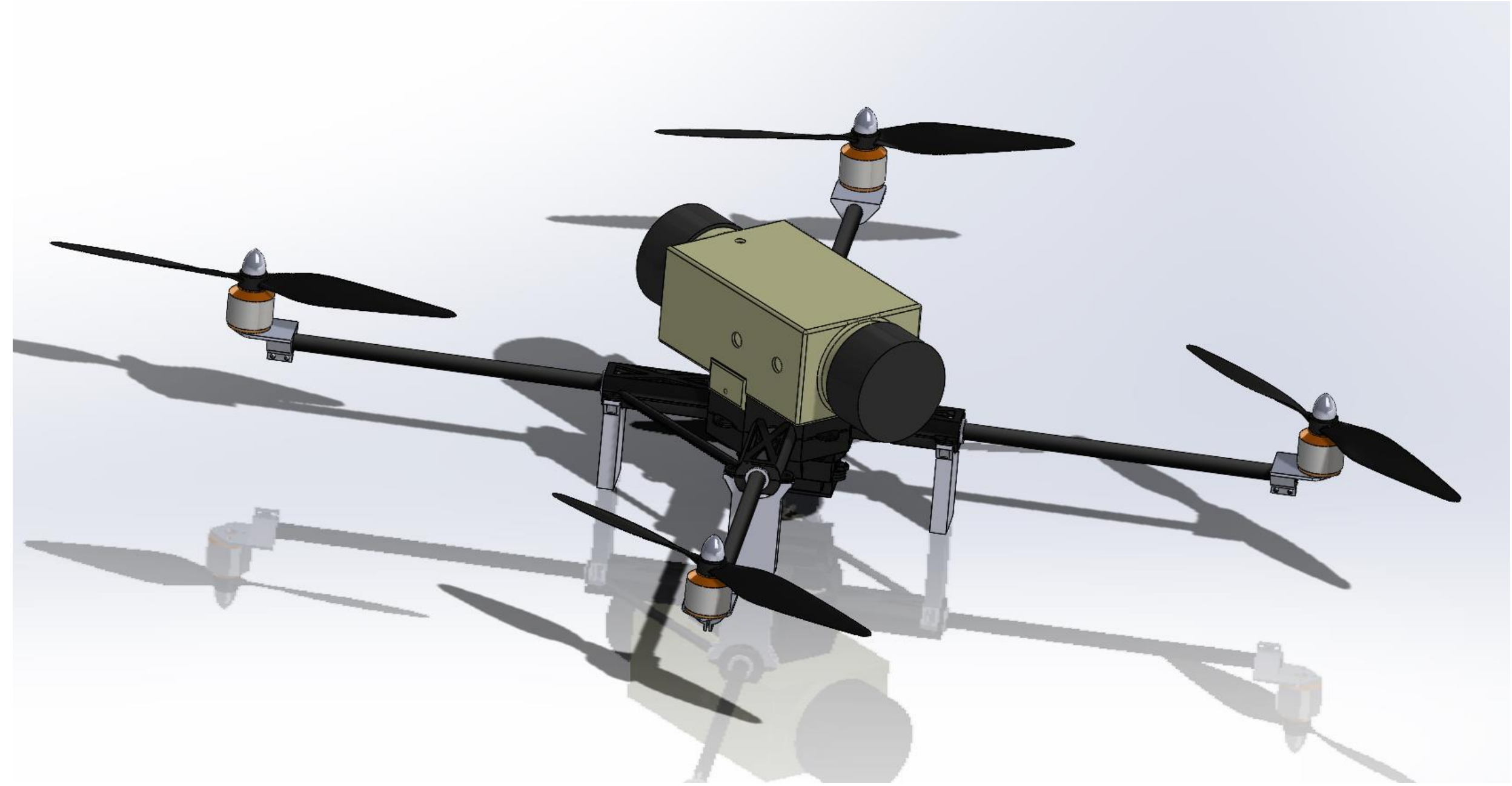








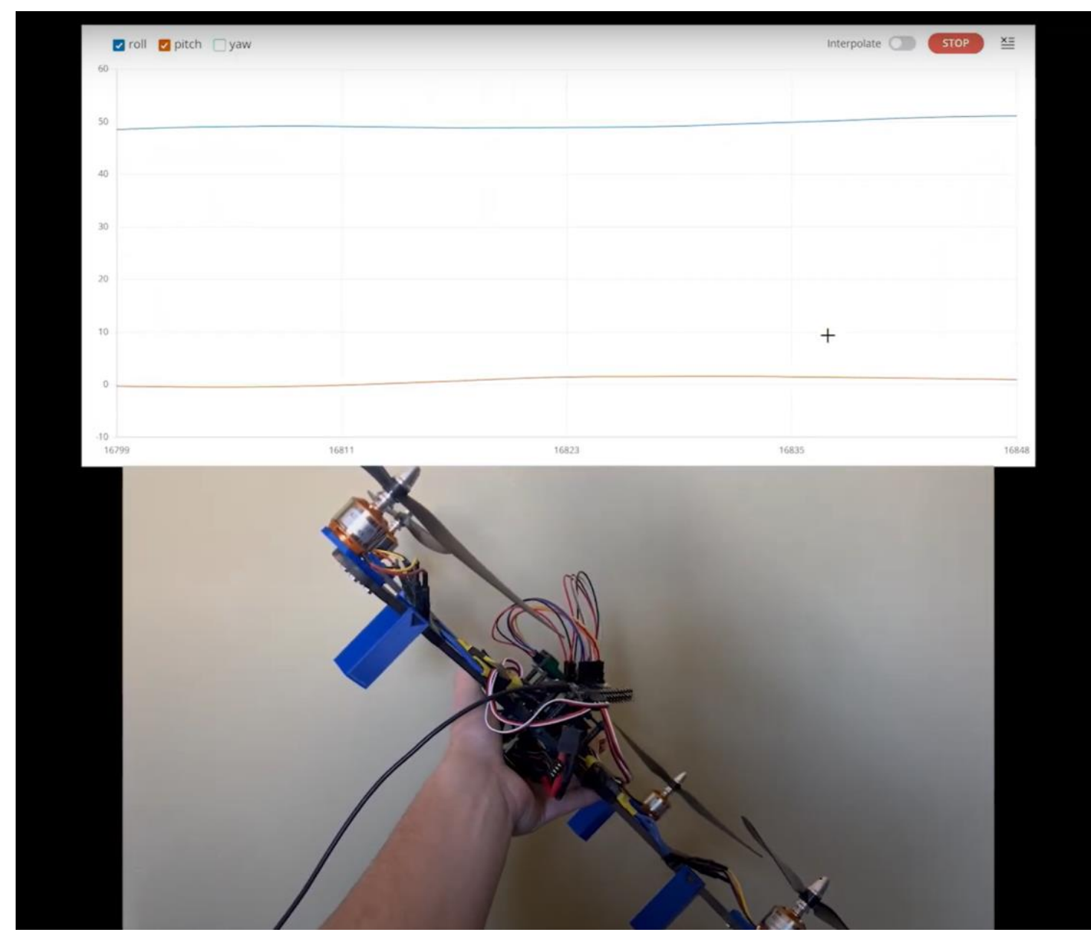




Prototype & Test Results

Flight Test Bed:

- Before flying our custom hull and servo design, we experimented with our flight controller, IMU, and code to understand how we would be able implement our custom configuration.
- Understanding how the IMU responds to different orientations was important for tuning our PID controller and allowing us to achieve controlled, stable flight with our drone test bed.



Hull Waterproofing and Depth Testing:

- We went through many iterations of the electronics hull to arrive at the current design. For each iteration of our design, we had to test the effectiveness of our waterproofing at different depths to ensure our hull was effectively protecting our electronics.
- Lowering our hull attached to a string marked in increments of 6" in the NBRF tank and waiting in increments of 5 minutes, we were able to assess how effectively our design prevented water ingress.