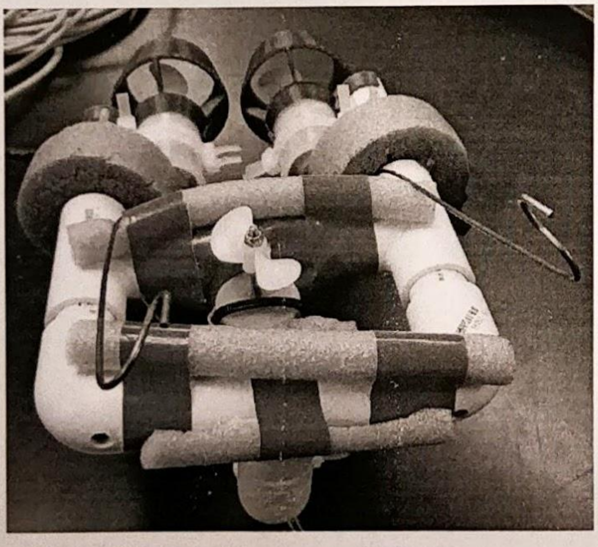
School: Andover High School

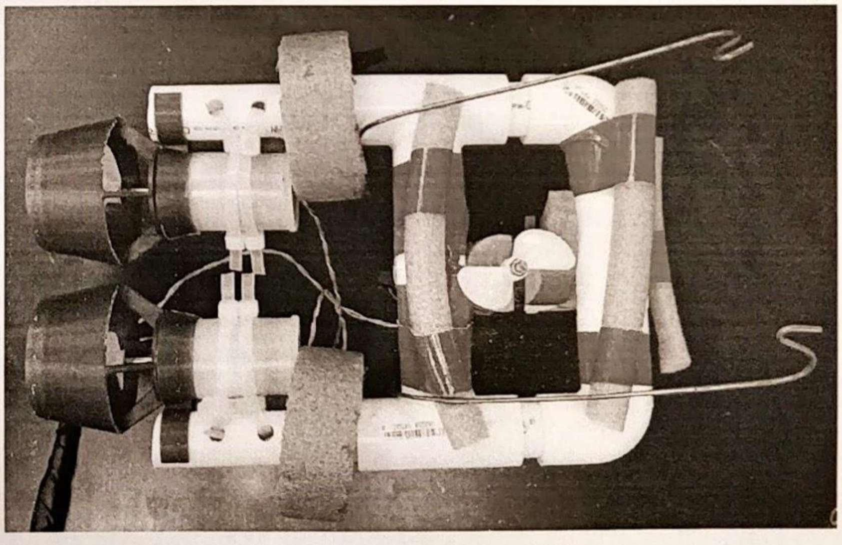
City, State: Andover, Massachusetts

Team name: Sharks

ROV name: Hammerhead

Project Shark Tank





Team Info

Teacher: Mr. Daniel Donovan
Email: ddonovan@aps1.net

Team Members:

Name	Grade	Role
Alex	11	CAD, Soldering, Coach
Curtis	11	PVC, Driver
Omkar	11	Lead Builder, Motors
Sarvesh	11	R&D, Prototyping & Testing, optimization
Aadith	11	R&D, Prototyping & Testing, Tester

Table of Contents

Engineering Design Process

Ask: Determine a problem

ex. How can we effectively traverse through the obstacle and at the same time efficiently pick up and drop off objects in the challenge?
ex. How can we improve the buoyancy of our vehicle to maintain neutral buoyancy with no object picked up?

Imagine: Brainstorm and document possible solutions

ex. Thinking about hooks, adjustable floats, small body, and Kort nozzles.

Plan: Create detailed design drawings

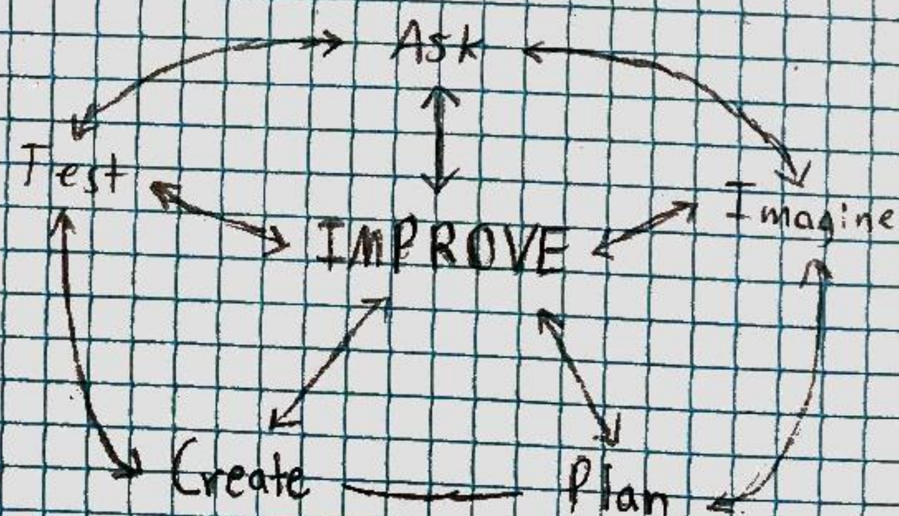
ex. Creating CAD models before making prototypes.
ex. Drawing diagrams of possible designs.

Create: Build prototypes

ex. Putting PVC pipes and connectors together following design plan.

Test: Follow test plans to test the prototypes

ex. Testing buoyancy in fishtank.
ex. Testing vehicle performance in Phillips Academy's pool.



Our idea of the Engineering Design Process

Brainstorming Methods to Pick Up Objects and Finalizing A System

Objective: To design a way to efficiently pick up the cubes, loops, and poles.

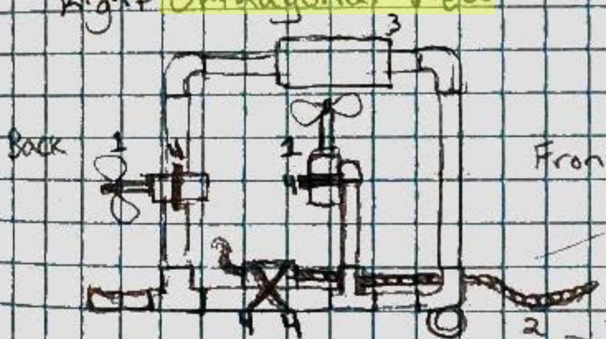
Tasks: 1) Look through the rules and scoring system and decide what strategy to pick
2) Try to incorporate possible design goals into one system
3) Finalize a rough method of gathering objects for the puzzle challenge (have rough idea)

Design Goals: 1) Compact and versatile 2) Light-weight
3) Retractable for obstacle course 4) Adjustable floats for obstacle course & challenge

Constraints: 1) Time (Regional Competition is on April 13) 2) Size (have to fit through the obstacles)
3) $20 budget

Designs:

Right Orthagonal View



Top Front Orthagonal View

1 = motor
2 = hook
3 = float
4 = Zipties

Testing at Phillips Academy Pool

Meeting Objective: To enhance driver practice and to adjust the robot according to performance.

Tasks: 1) Set up obstacle and challenge course underwater
2) Test robot and driver performance

Testing Procedure: Obstacle Course
1.) Define what we need to test: speed/time through course
2.) Set up experiment: Each member drives and is timed through pre-made obstacle course

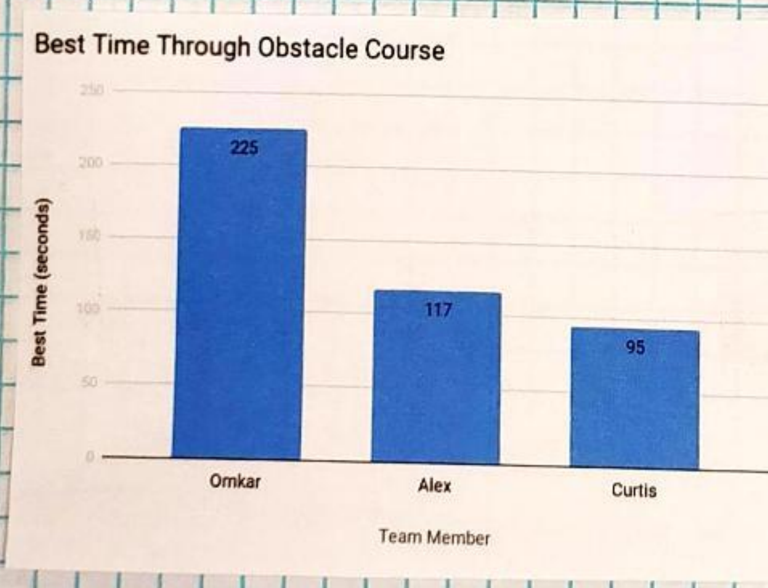
Challange
1.) Define what we need to test: How easy it is to pick things up, maneuver, and drop them
2.) Set up experiment: Drive ROV to manipulate each object and place them onto pre-made platforms

Testing Limitations:
- Lighting at Phillips was brighter than in most other pools
- Didn't have origin platform for practice
- Looped PVC pipes weren't upright (had to pick them flat off the floor)

Issues & Solutions:
- Visibility underwater with the refraction of light can make it hard to see
  - Solved through practice and predicting movements of the ROV
- Cable management as it is fed through by the coach
  - solved by coiling the cable naturally and using the battery as a hold

Testing Results:

Name	Time
Omkar	3min, 45 sec
Alex	1min, 57sec
Curtis	1min, 35sec



Curtis will drive at the regional competition.

Regional Competition at UNH-Durham

Best Obstacle Course Time: 1min, 47 sec

Other Obstacle Course Time: 1min, 47 sec (200ms difference than best time)

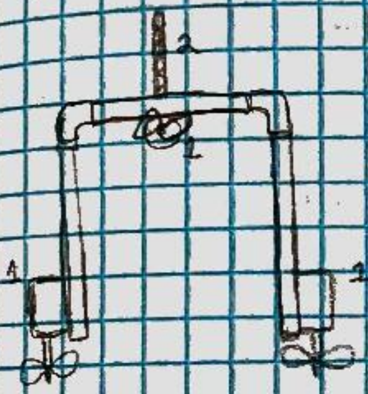
Challenge Score: 15 (6 upper, 3 lower in 14min, 52 sec)

Result: 2nd Place

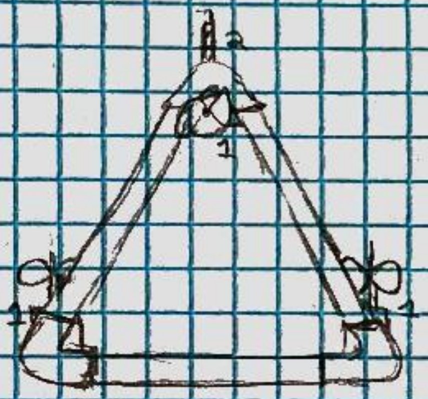
Difficulties Encountered: 1) Couldn't see wire underwater (wire got tangled)
2) Hard to pick up loops attatched to pvc pipes
3) Reached surface too slowly

Possible Improvements: 1) smaller, more maneuverable design
2) put neon tape on hook and wire more visible
3) Maybe make robot out of 3D printed parts that are smaller

Design Ideas:
Top Orthagonal View



or



1 = motors
2 = hook

Optimization of Torque, Center of Mass, And Buoyance

Torque = rotational force $\vec{\tau} = \vec{r} \times \vec{F}$

Since torque causes objects to rotate around an axis, we want to minimize the net torque on our robot (ideally zero).

Center of Mass = distribution of mass with regard to a relative position
- Can treat objects as points with all the mass concentrated at center of mass

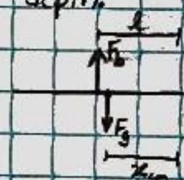
Center of Buoyancy = where net buoyant force is acting on an object
- Center of mass of fluid displaced

center of mass : $x_{cm} = \frac{\sum_{i=1} m_i x_i}{m_{tot}}$ buoyant force : $F_b = \rho g V$ (ρ = density of fluid, $g = 9.8\,m/s^2$, V = volume of fluid displaced)

The force of buoyancy, the force pushing our robot upward, is constant regardless of the depth of our vehicle. This means that as we submerge our vehicle deeper underwater, the upward buoyant force and the downward force of gravity are constant, while the downward force of the water pressure increases, making it more and more difficult for us to move up at a deeper depth.

Torque diagram with no object picked up:

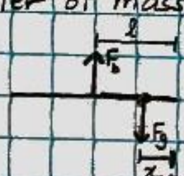
$\Sigma\tau = F_b l - F_g x_{cm}$



When we pick up an object, the center of mass shifts towards the position of the object.

Torque diagram with object picked up:

$\Sigma\tau = F_b l - F_g x_{new}$



Therefore, to minimize rotation, the center of mass has to be located as close to the center of buoyancy as possible, and the center of mass can't change too much when we pick up an object. Our center of buoyancy has to be above our center of mass in order to have our vehicle be self-righting and keep our vehicle level.

Sources: KhanAcademy, Study.com

Kort Nozzles

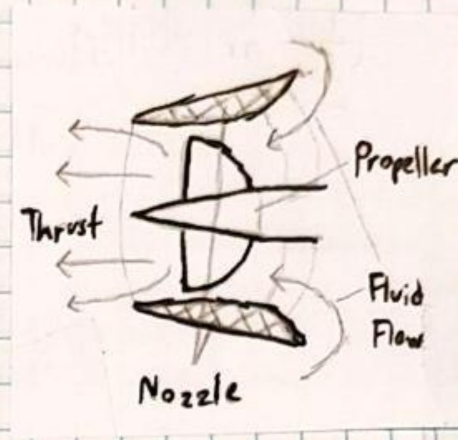
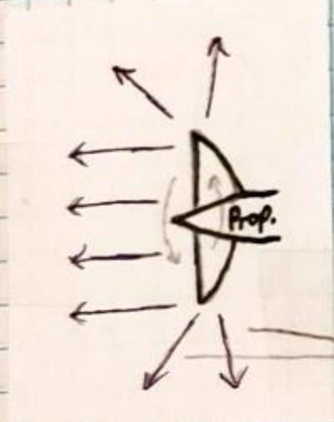


Fig. 5.1 - Side View of a Kort nozzle and propeller. Arrows indicate fluid flow.

Question: what is a kort nozzle?
- Our definition: a nozzle that goes over the propeller to increase efficiency and thrust of the propeller
- Wikipedia: "a marine propeller fitted with a non-rotating nozzle. It is used to improve the efficiency of the propeller (Wikipedia)

Why does a kort nozzle work the way it does?

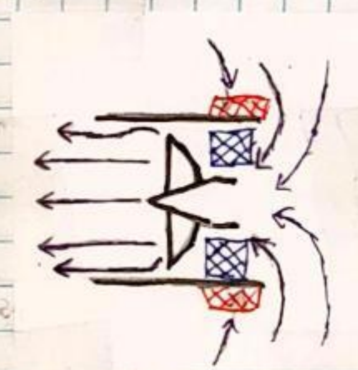
← = water flow   ☒ = high pressure   ☒ = low pressure



As the propeller spins, a lot of water is used as thrust, but some water spins off, not being used for thrust

"Wasted" water

Fig. 5.2



Using a kort nozzle, this water is redirected to increase thrust. If the nozzle is extended, it can also create high and low pressure zones, forcing more water to flow in

Fig. 5.3

Sources: Mantzel, J and RC Model Reviews

Kort Nozzle Prototype 1:

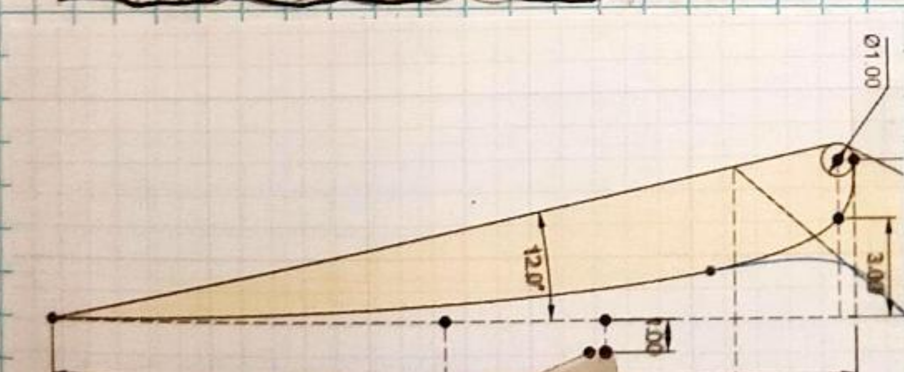


Fig. 5.4 - Side geometry of the Kort nozzle

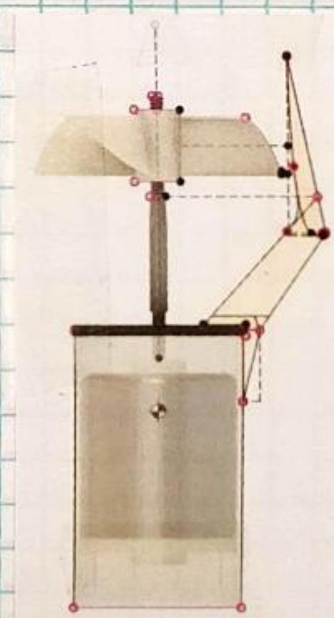


Fig. 5.5 - Side geometry of the kort nozzle with respect to the motor and propeller shaft

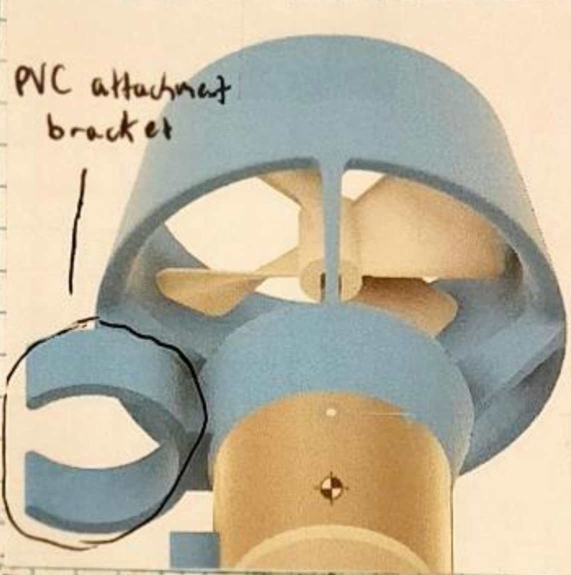


Fig. 5.5 - Inside view of the Kort nozzle

Fig. 5.6 - Outside view of the Kort nozzle

Finished Print

Material Type: PLA

Estimated Weight: 49.07 grams

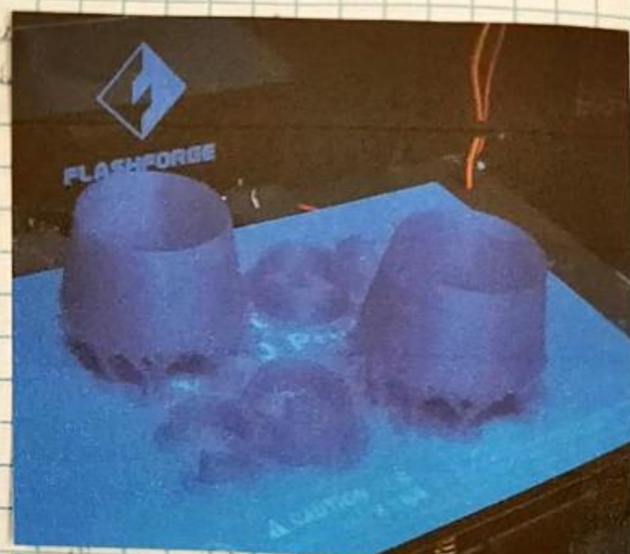


Fig. 5.7 - The finished print on the build plate

Fig. 5.8 - Side view of the finished Kort nozzle print

Fig. 5.9 - Top view of the finished Kort nozzle print

CAD Prototype Designs

Objectives:
- Create as small an ROV as possible
  - We want the ROV to go through the obstacle course quickly
  - Making a smaller and lighter ROV should maximize the effect of the motors' thrust on the ROV
- Make it as hydrodynamic as possible
  - More hydrodynamic → higher motor efficiency
    ↳ lessened effect of drag on the ROV
- Keep the lift motor above the center of mass or in front of it
  - Motor in front → lift motor changes the ROV's pitch
  - Motor above center of mass → lift motor lifts / sinks the ROV
  - Motor behind → lift motor inversely changes the ROV's pitch

Focus: Center of Mass → why is it important?
- Locating the center of mass is beneficial to predicting the ROV's movement
  - For example, once the ROV picks up a cube, the center of mass shifts to the front of the ROV. This could be problematic if the ROV was not built with this in mind.

Design 1: Flatfish

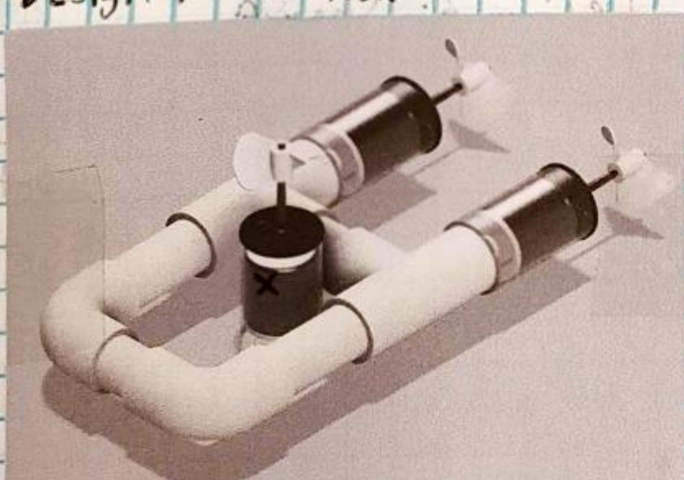


Fig. 6.1.1 - Full view of Flatfish

Pros:
- very small in general
- very fast ROV

Cons:
- Might struggle to pick up objects
- Center of mass would shift a lot when picking up objects
- Impractically small
- Easy to flip over

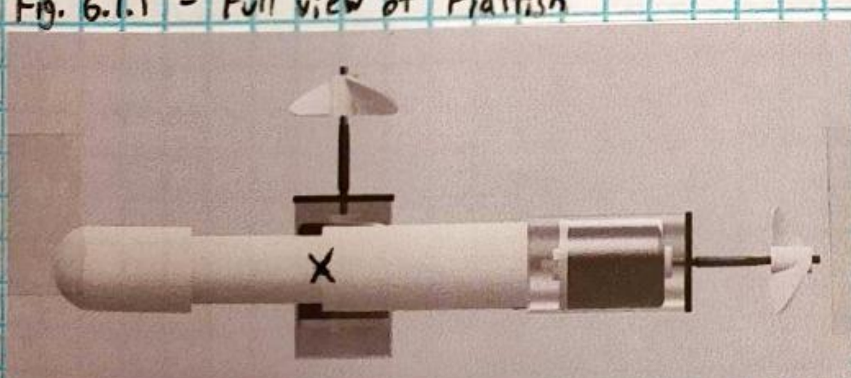


Fig. 6.1.2 - Side view of Flatfish

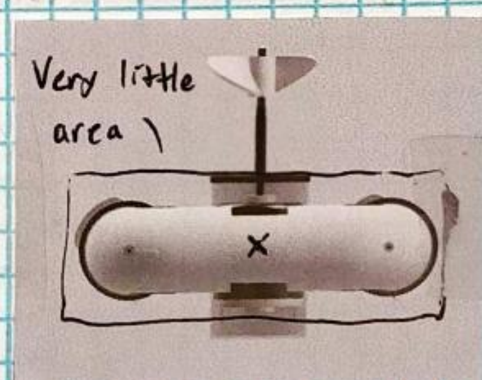


Fig. 6.1.3 - Front view of Flatfish

Design 2: Sailfish

Pros:
- very streamlined front profile
- floats placed on the pipe can be easily moved and adjusted

Cons:
- No clear placement for lift motor
- May struggle to turn
- More likely to tilt over on its side

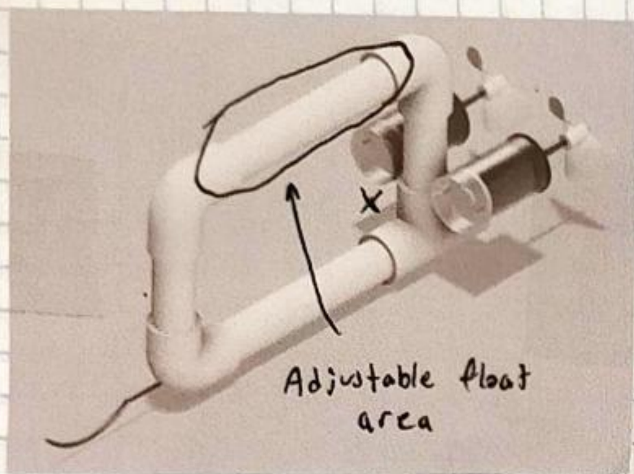


Fig. 6.2.1 - Full view of Sailfish

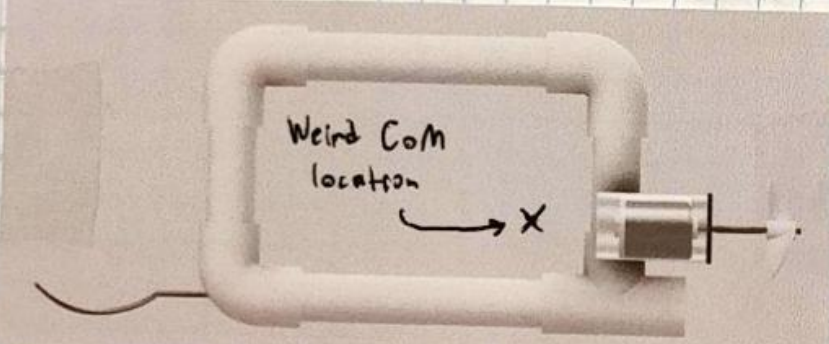


Fig. 6.2.2 - Side view of Sailfish

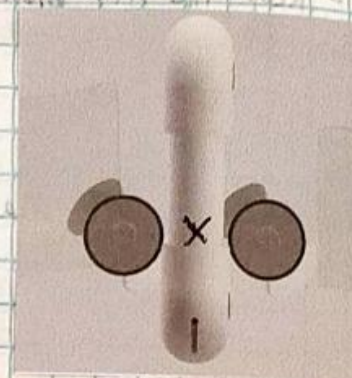


Fig. 6.2.3 - Top view of Sailfish

Design 3: Sharkfin

Pros:
- Design stays flat on the ground easily
- Can adjust back float placement

Cons:
- Center of mass is in front of the lift motor

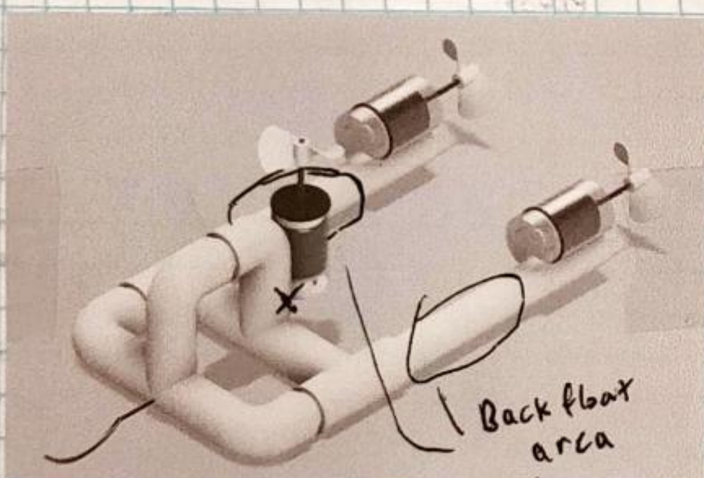


Fig. 6.3.1 - Full view of Sharkfin

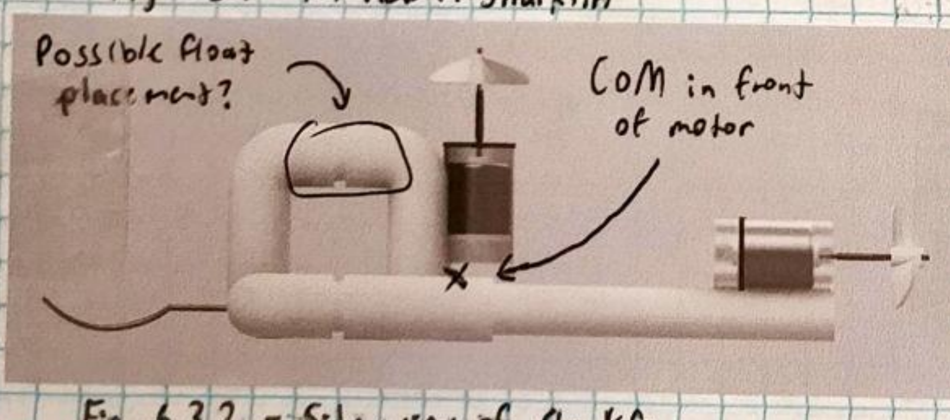


Fig. 6.3.2 - Side view of Sharkfin

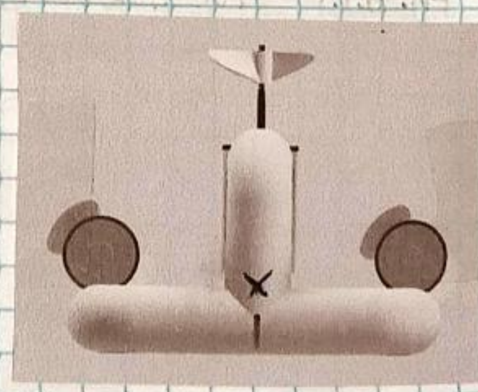


Fig. 6.3.3 - Top view of Sharkfin

Design 4: Hammerhead

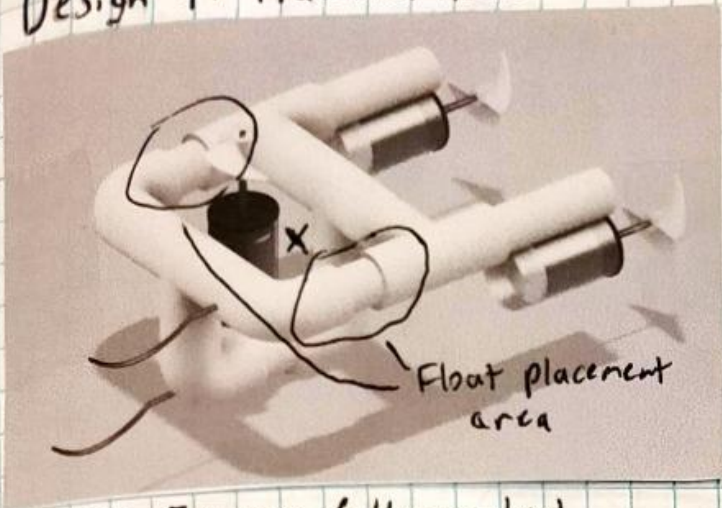


Fig. 6.4.1 - Full view of Hammerhead

Pros:
- Lift motor can be in front of center of mass
- Two great places to put floats

Cons:
- Might struggle to stay upright

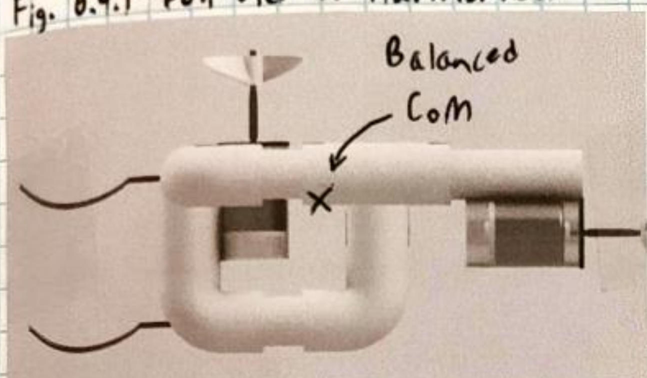


Fig. 6.4.2 - Side view of Hammerhead

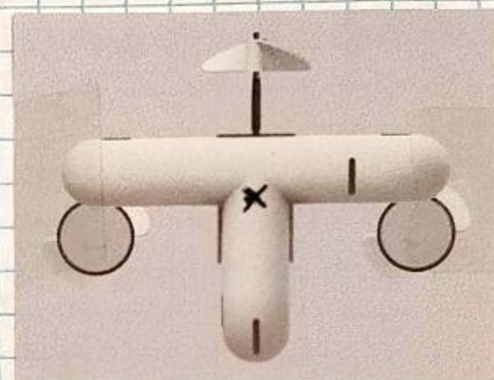


Fig 6.4.3 - Top view of Hammerhead

We chose to prototype the Hammerhead design because the motor is in front of the center of mass, which is beneficial when we pick up any objects, as the center of mass will shift to near the vertical propulsion motor. Then, the net torque will be minimized, so our vehicle will not rotate as much. This design seems to be the most stable of our designs, and it allows us to put the bottom hook (meant for the cube) in the center of the front plane of our vehicle, so the heavy cubes will not create angular velocity about our x-axis (limit our roll). The second layer also allows us to add a second hook meant for picking up the looped PVC tube.

Double-Decker System

By Reasearch and Development Team (Sarvesh and Aadith)

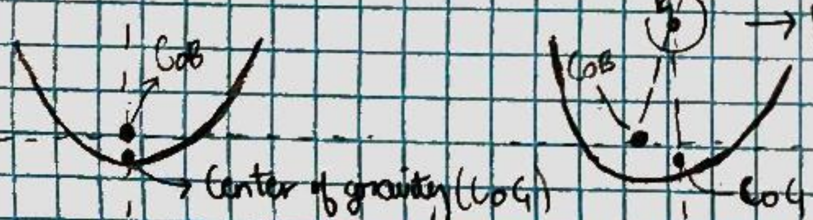
Buoyant force (F_B) = density (kg/L) · gravitational field strength ($\frac{m}{s^2}$) · Volume (L) $\left(\frac{kg \cdot m}{s^2} = \text{Newtons}\right)$

- Center of buoyancy is the position where all buoyant forces will have an influence on the object i.e where the net force acts on the object.

Optimum Setup:

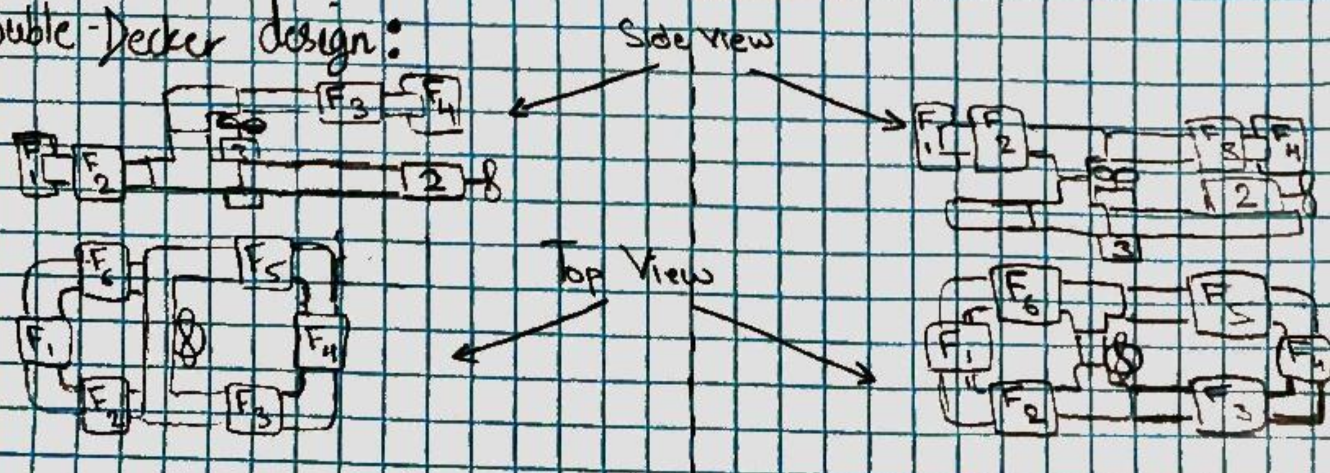
→ Having the center of buoyancy (CoB) right above the center of gravity of the object, belonging on the same axis perpendicular to the base.

→ All buoyant forces must be balanced across the chassis to prevent a moment force (net torque) around the center of gravity and flipping the ROV

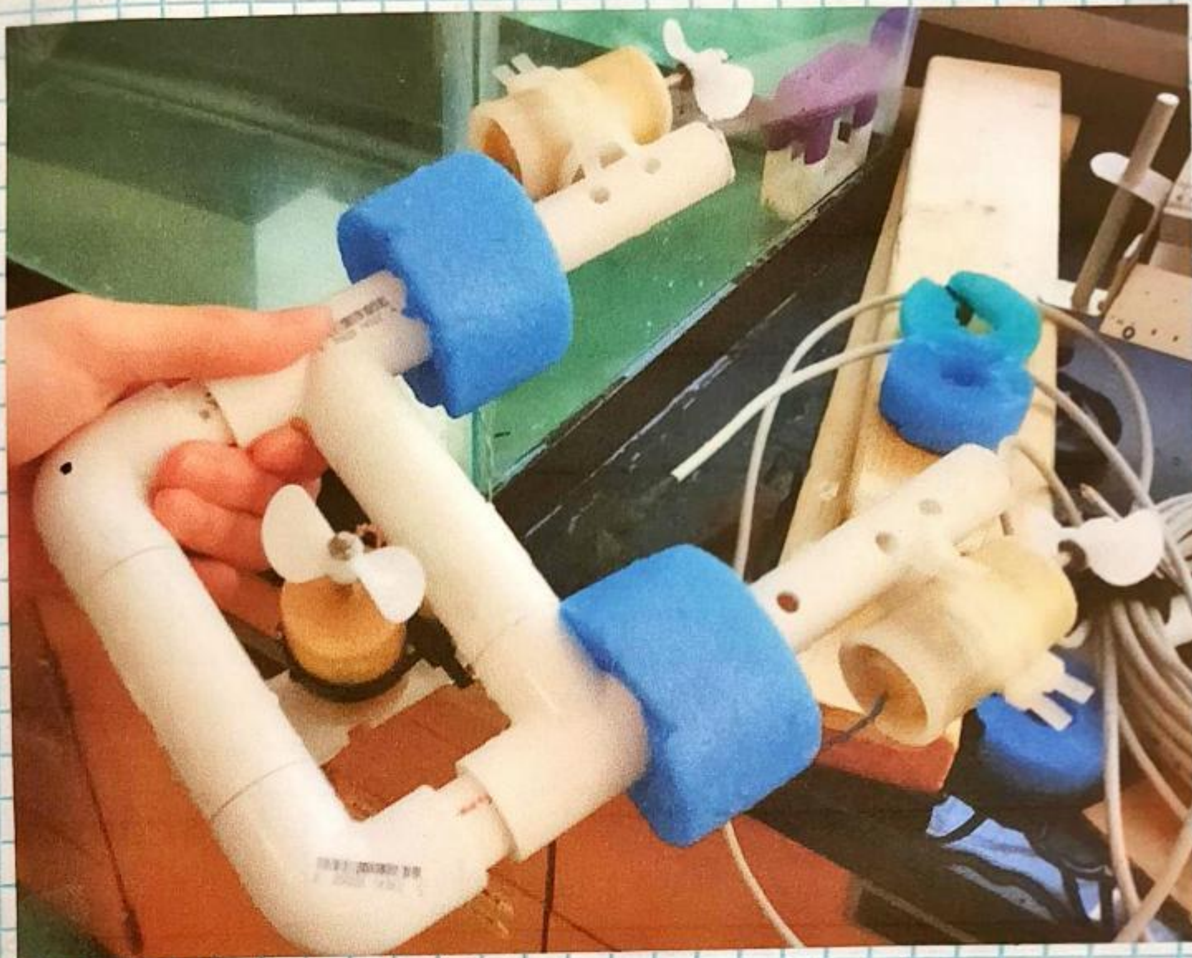


→ Force applied by CoB across to force readjustment and righting

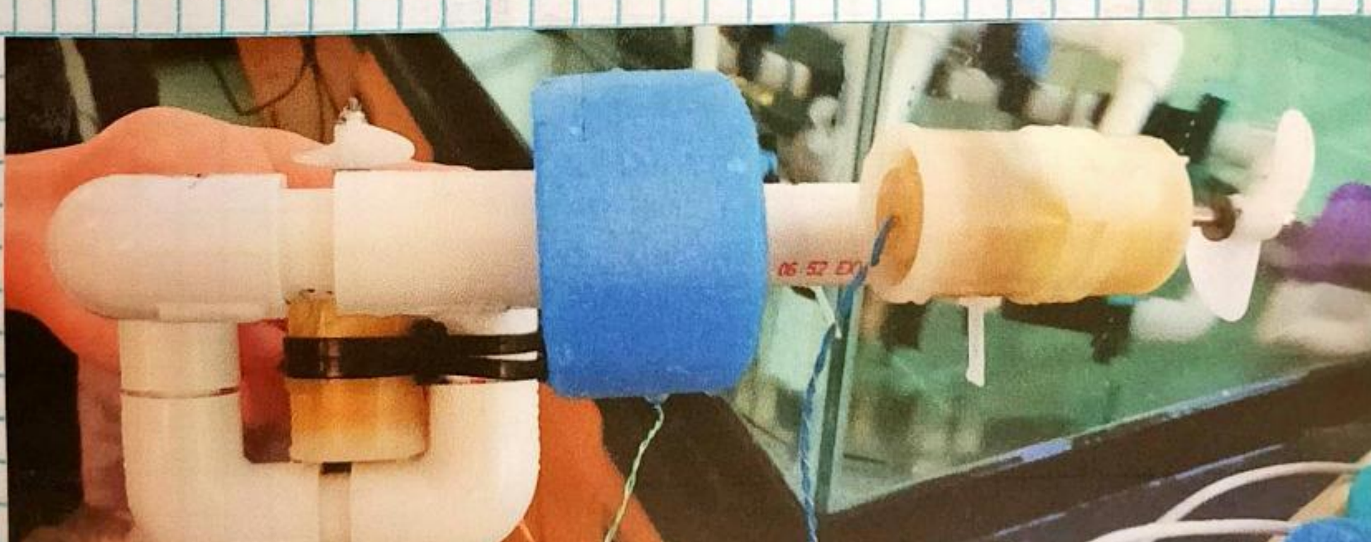
Double-Decker design:



Building Hammerhead Prototype



We built our Hammerhead body using only the original parts that from our base kit. We obtained new zipties for attatching the motors.



Side View

Creating Hooks for the Hammerhead

<u>Objective:</u> To create a hook system using our old hook for the new hammerhead design

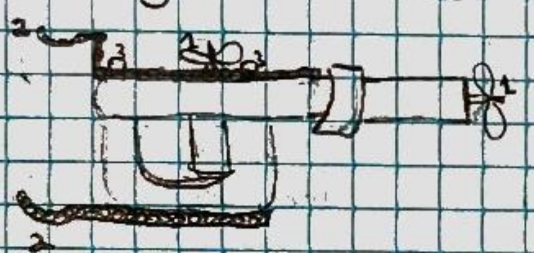
<u>Tasks:</u> 1) Procure enough hooks for our multilevel hooks
2) Straighten the body while bending the ends
3) Place and test hooks in the tank with objects

<u>Design Goals</u>: 1) Thin enough and low enough to fit through cubes
2) Top hooks for looped tubes which are offset from the bottom hooks which are for the cube
3) Lightweight

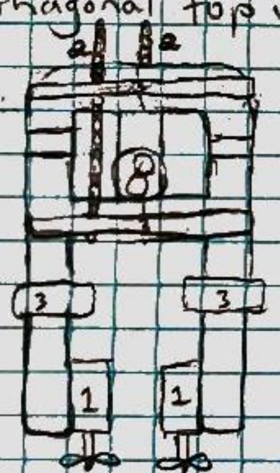
<u>Designs:</u>

1 = motors
2 = hooks
3 = floats

1) Orthagonal left view

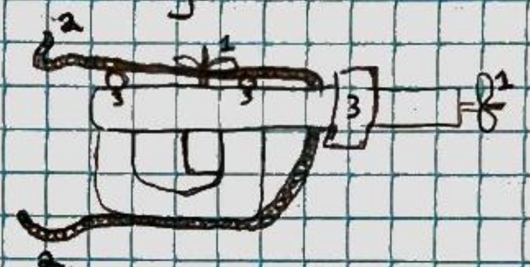


Orthagonal top view

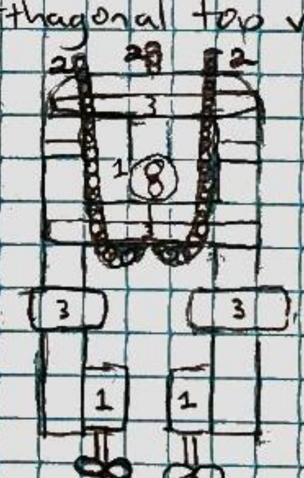


This design was too imbalanced especially after lifting the looped tubes. Also uses two seperate hooks

2.) Orthagonal left view



Orthagonal top view



This design uses one long hook, makes the ROV more balanced after lifting the looped tubes, and sends more of the weight to the back. However this design is heavier

In the end we chose design 2 because it was more balanced and thus less likely to drop an object during transportation.

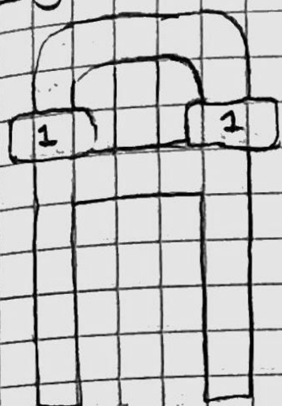
Finding the Right Buoyancy for the Hammerhead

Objective: To create a nearly neutral but slightly positively net buoyancy for the new hammerhead design

Tasks: 1) Create different sized floats from larger floats
2) Trial and error test drive in the tank

Designs: 1= Tube floats 2= backer foam 3= hook

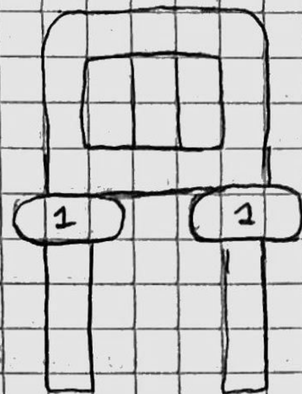
1)



Orthagonal top view

This design was too buoyant in the front causing the front to pitch upwards.

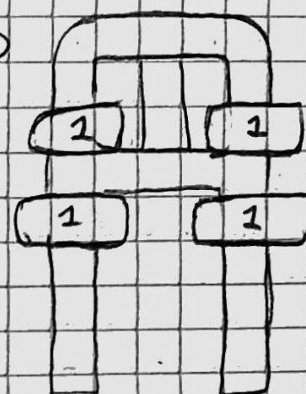
2)



Orthagonal top view

This design was too buoyant in the back causing the back to pitch upwards

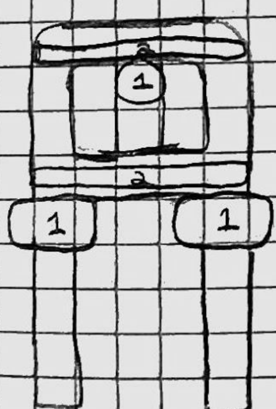
3)



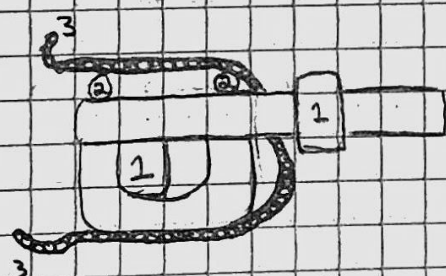
Orthagonal top view

This design was too overall buoyant but kept the ROV more leveled than the previous designs

4)



Orthagonal top view



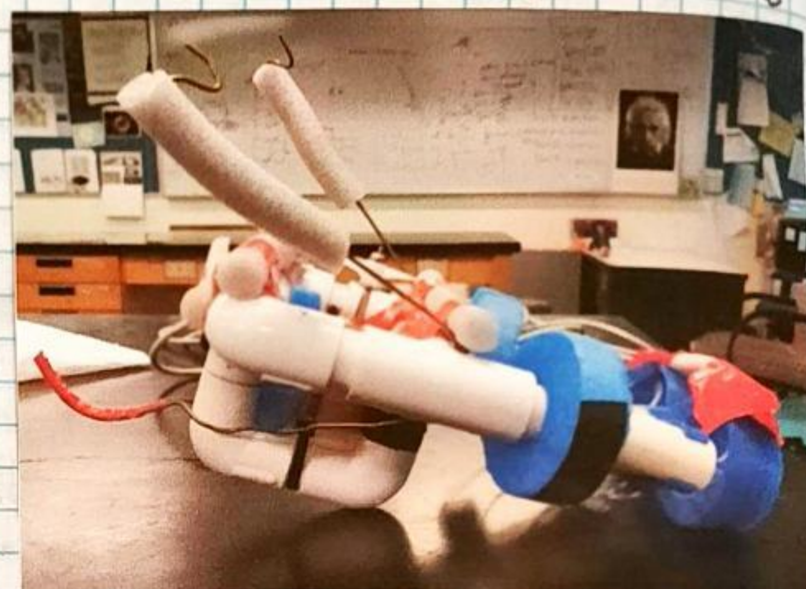
Orthagonal left view with hooks

This design was our final design. It provides a slightly positive buoyancy with no objects, it's center of buoyancy is further up preventing the ROV from flipping over, and the top snake tubing provides support for the hooks.

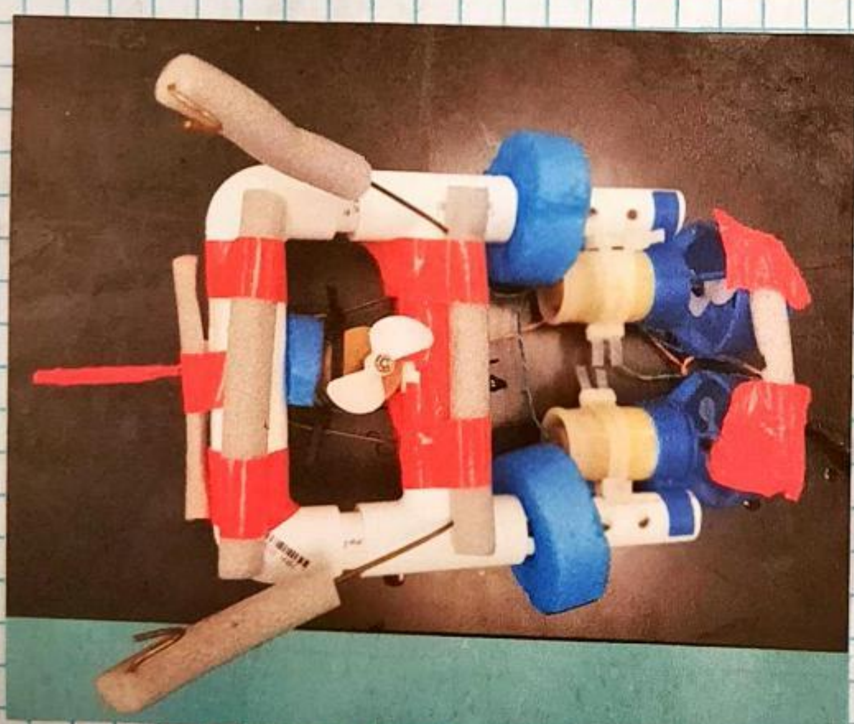
Pictures of Final Hammerhead

Front View

Here you can see the angled top hooks



Side View



Top View

Our adjustable floats are on the hooks

Our hook bends down to be level with the ROV base while the end bends up to be at the same level as it started

Budget

Item Name	Quantity in Package	Cost of Package	Unit Cost	Amount Used	Cost for Item
5/8" Backer Foam	20 ft	$3.97	$0.20	3 ft	$0.60
Steel Hangers	5	$7.92	$1.58	1	$1.58
Zipties	100	$2.74	$0.03	20	$0.56
Duct Tape	1 roll	$3.89	$3.89	1 roll	$3.89
PLA 3D Printed Material (measured in grams)	N/A	N/A	$0.025 per gram	49g	$1.225

Total Cost: $7.30

References

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