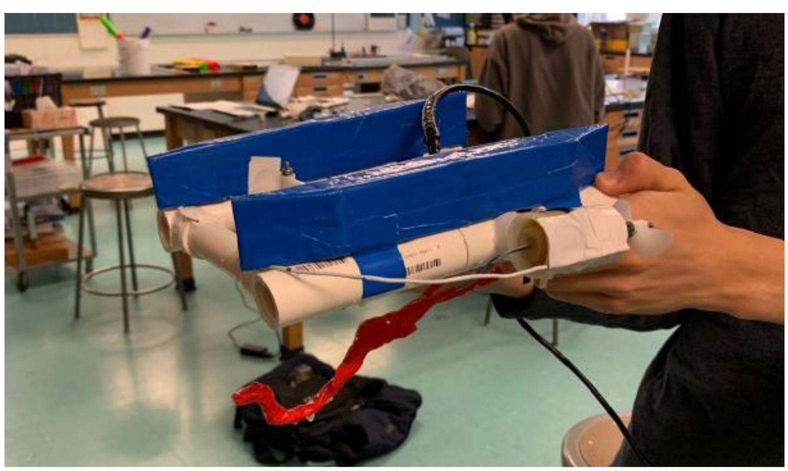
School: Andover High School

City, State: Andover, Massachusetts

Team name: Sharks

ROV name: Jaws

Project Shark Tank



Team Information Page

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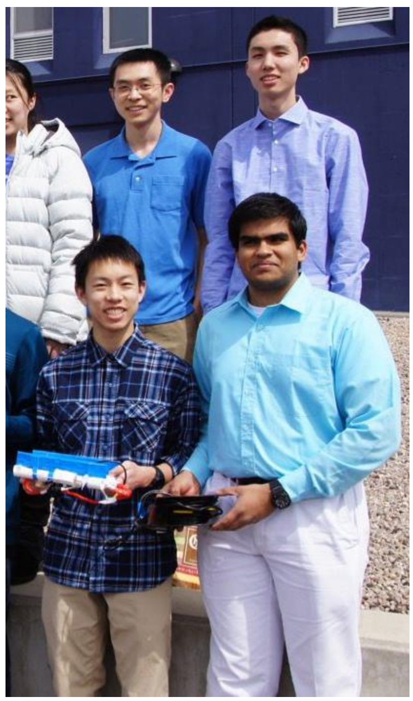


Table of Contents

Engineering Design Process

Ask: Determine a Problem

Ex: What type of frame will be stable while also providing the most speed?
Ex: What is the best way to pick up an object and transport it?

Imagine: Brainstorm and Document Possible Solutions

Ex: Discussing types of frames, intake systems, hook shapes, etc

Plan: Create detailed design drawings

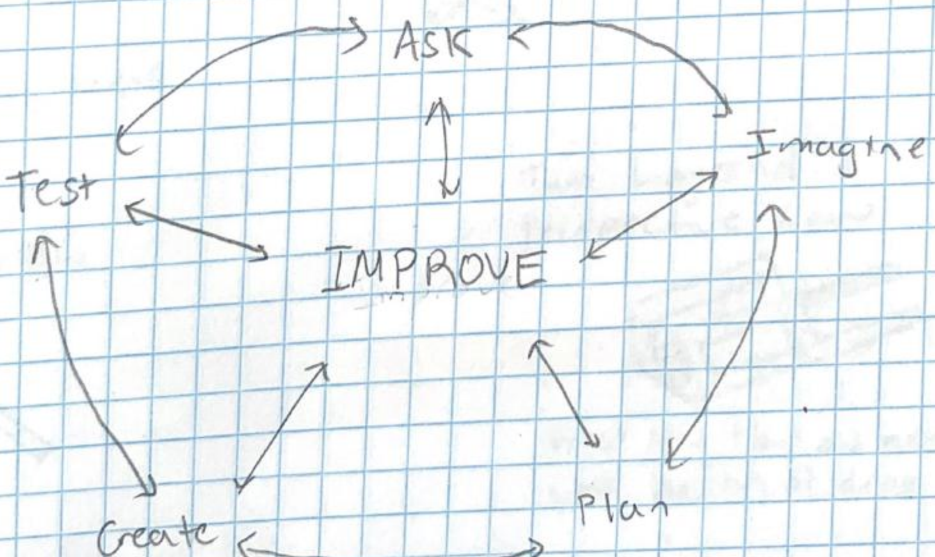
Ex: Drawing and labeling diagrams during discussions.

Create: Build Prototype

Ex: Putting PVC pipes and connectors together following design plan

Test: Follow test plans to test the prototypes

Ex: Testing buoyancy in fish tank
Ex: Testing vehicle performance at Greater Lawrence Tech's pool



The Engineering Design Process is all about improvement in order to create the best possible solution for a problem.

Brainstorming Frame

Objective: Design a sturdy hydrodynamic frame that is as light as possible

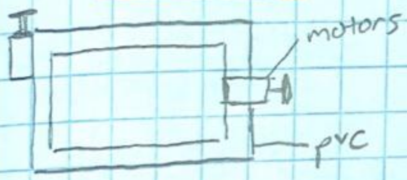
Tasks:
1) Brainstorm frame designs with sketches
2) Discuss pros and cons of ideas
3) Choose the final design

Design Goals:
- cheap
- sturdy
- lightweight
- good hook placement
- good float placement
- hydrodynamic

Constraints:
- $25 limit
- 18" by 18"
- time

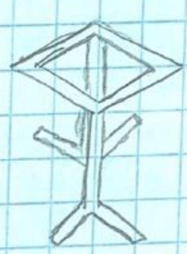
Designs:

Flat Fish:
Left Orthagonal View



Pros: hydrodynamic
cons: low turning torque

Table:
Perspective view

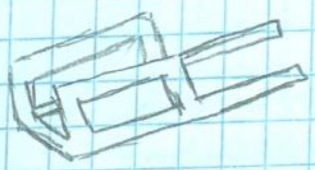


Pros: sturdy, self-standing
Cons: bulky, lots of drag, heavy

Pyramid:
Perspective View

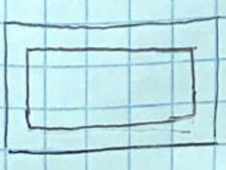
Pros: triangles are strong, self-standing
Cons: bad motor placement, not hydrodynamic

Two Layered:
Perspective View



Pros: Good float and motor placement
Cons: big, lots of drag

Flounder:
Top Orthagonal View



Pros: good turning torque
good hook placement
Cons: nothing noticable

*We chose this design because it had the least cons.

Brainstorming Intake

<u>objective</u>: To design a way to efficiently pick up balls and broken ROV

<u>Tasks</u> 1) Brainstorm intake system with sketches
2) Discuss the pros and cons of each design, prototype some
3) Finalize a rough method of gathering objects

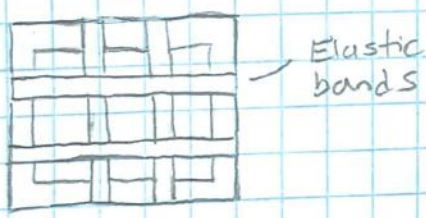
<u>Design Goals:</u> • Cheap • Easy to make • Can pick up all objects • stable

<u>Constraints:</u> • \$25 budget • Time • 18" by 18"

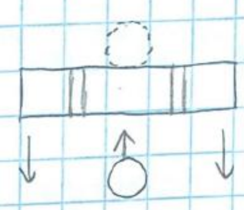
<u>Designs:</u>

Ketchup Bottle:

Top Orthagonal View



Side Orthagonal View

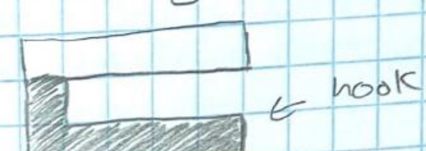


The ball is pushed through the bands and stays on top because there's tension

Pros: Unique, cheap, easy to make, works will all ball sizes, cheap
Cons: Requires flipping to drop object, only picks up balls

Hook:

Side Orthagonal View



Pros: Can pick up all objects, can be made out of different materials, Cheap, easy to drop objects
Cons: Not unique

Other ideas that were not prototyped for demonstration:
• crane • scoop • net • basket • bulldozer

<u>Final Decision:</u>
We have decided to go with the hook because there aren't any real cons, we've had previous experience using hooks, and it still leaves freedom for modifications.

To address the beacon aspect of the challenge, we will build a tube or "cup" that goes ontop of the beacon and slides down so attatched magnets can activate the sensor and cause the Hall Effect. Cup designs discussed later.

Building the Hook

Objective: To create a hook that can consistently pick up objects

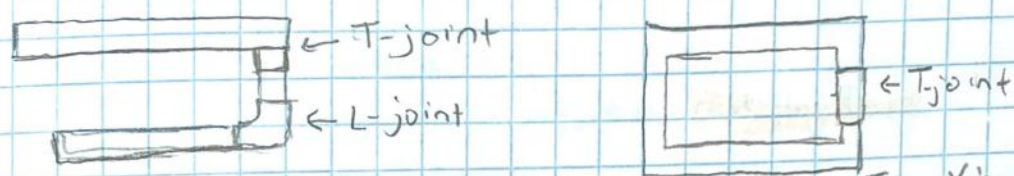
Tasks: 1) Obtain materials 2) bend/mold shape 3) secure onto ROV
4) Modify

Design Goals: • Cheap • Lightweight • Thin • Sturdy • Can be reoriented

Constraints: • 18" x 18" size • Money • Time

Designs:
PVC Hook:
.84 in OD .622 in ID SCH 40 1/2" PVC

Pros: Easy to make
Cons: Thick, unsecure



Orthagonal Side View

Orthagonal Top View

Metal Hook:
2 metal clothes hangers twisted together and taped over

Orthagonal Side View

Orthagonal Top View

ducttaped over

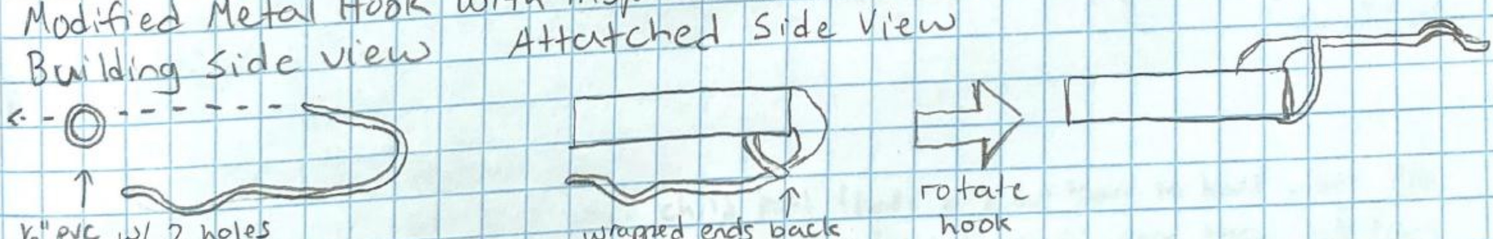
Pros: Sturdy, Secure, Cheap

Cons: Bulky

Shark Jaw: (Current)
Modified Metal Hook with inspiration from Austin Prep and shark jaws

Building Side view

Attatched Side View



1/2" pvc w/ 2 holes drilled 2" apart

wrapped ends back down for support

rotate hook

Pros: Can rotate hook (like jaw) so it doesn't get caught in obstacle and can start further from the wall, Sturdy, Secure, Cheap, Unique
Cons: None noticed yet

We tried placing the hump under the up and down motor so that the object wouldn't cause excessive pitch change

Floatation

Objective: Attach floatation to the ROV so that it is just slightly above netural boyancy.

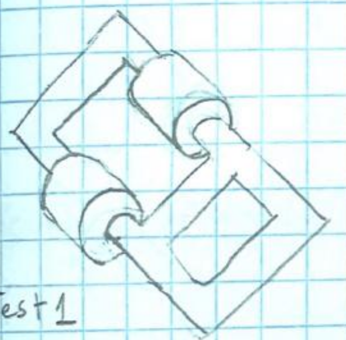
Tasks: 1) Choose a material 2) Choose a design 3) Create and attatch

4) Test / revise

Design Goals: • Cheap • hydrodynamic • balances the ROV

• fits on frame

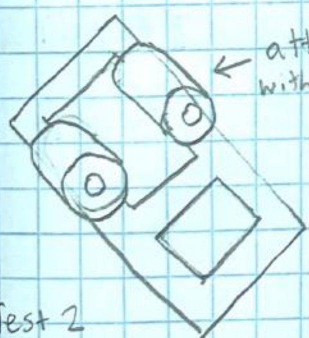
Designs:



Test 1

Problems:
• not top boyant / no restoring force
• unstable
• up and down propeller above water

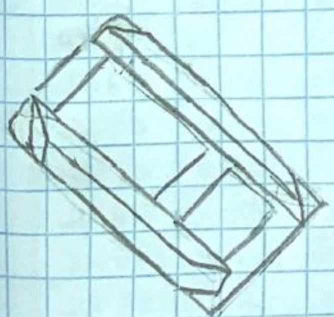
Floats in line with PVC



Test 2

Problems:
• heavy drag
• not very secure
• zipties dig into the foam which changes the density / boyancy

Floats ontop PVC



Test 3
(custom trapezod / current)

Assembly:
We took used child pool floats and cut them in half where the belt goes through the middle. Right trapezoids were then cut from the halfs and then put back to back to create a long trapezoid. The trapezoids were covered with duct tape.

Benefits:
• Much more hydrodynamic than the others
• Distributed floats allow for better stabilty
• Distributed floats allow for automatic counterrotation when the ROV is tilted.

Tether Management

Objective: Create an easy means of reeling in the tether

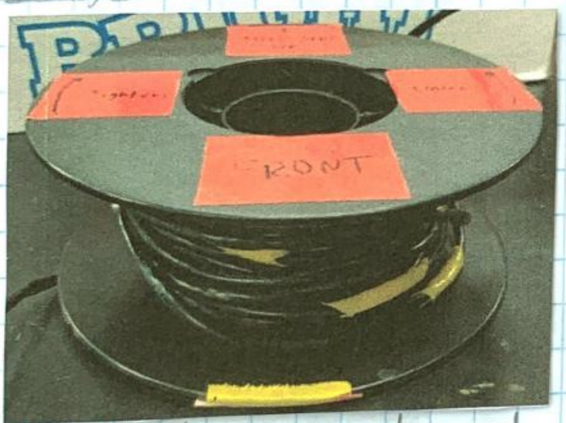
Design Goals: • easy to use • effective • quick
• high visibility

Constraints: • very low cost

The Idea:

Since we were using 3D printing, we had the idea of repurposing the spare filament spool for use as a way of quickly giving slack to and pulling in the tether. Also, extra slack can be detrimental, as it can get tangled in the course.

Design:

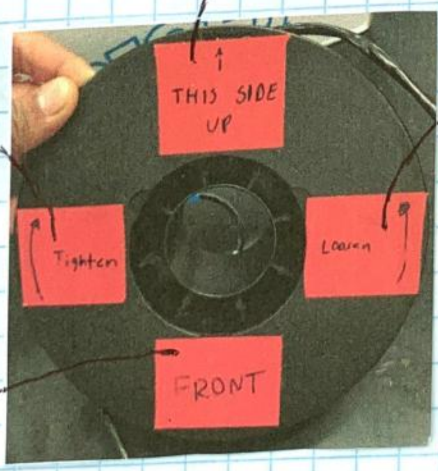


Our tether management spool

We drilled a hole to thread the tether cable through the spool. While working, we quickly realized that the spool could not spin because the other end of the tether would get taught.

To solve this, we decided to keep the spool stationary wrap our hand around the spool, similar to a fishing rod.

This side is up



Rotate your hand around clockwise to reduce slack on the tether and limit the range of the ROV

Rotate your hand around counter-clockwise to add more tether so the ROV can travel farther out

The front should face out towards the pool and the mission / obstacle course.

During our testing, this spool works really well! We can adjust the tension of the tether, which improves our performance - no tangles.

Computer-Aided Design (CAD)

Objective: Visualize our designs digitally, manufacture parts that are difficult to make by hand, and better

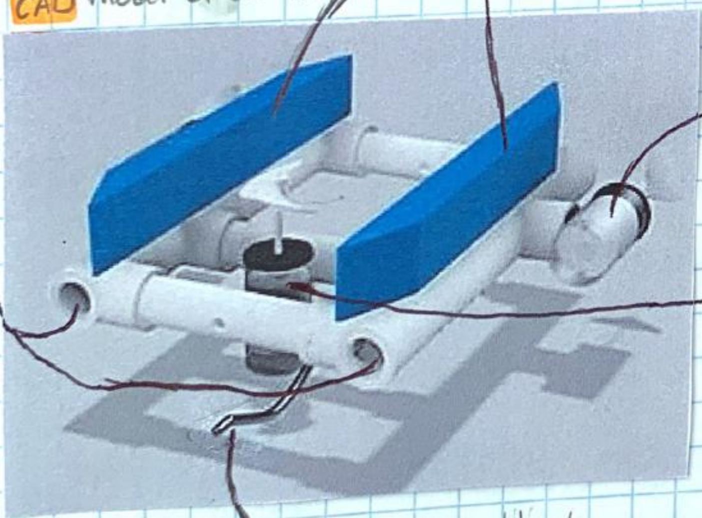
Tasks:
- Design cup for triggering beacon (in next section)
- Plan and design ROVs
- Create hydrodynamic thruster caps

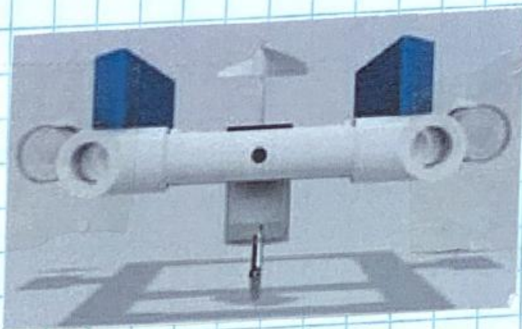
☆ Plan and design ROVs - Why?

CAD is helpful in visualizing the design, checking spacing of parts, and estimating the ROV's center of mass. If necessary, CAD can also allow us to visualize how water flows around the ROV (hydrodynamics)

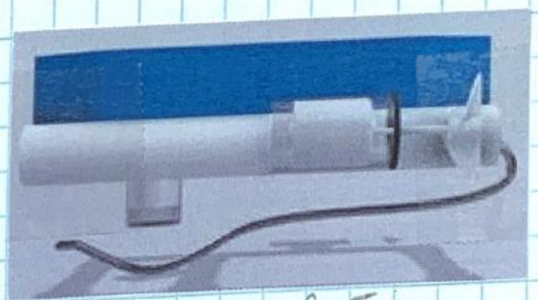
Design - Jaws (Flounder frame)

CAD Model of our ROV





Front view of Jaws



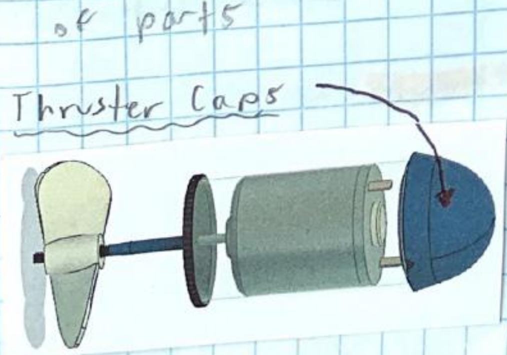
Side view of Jaws

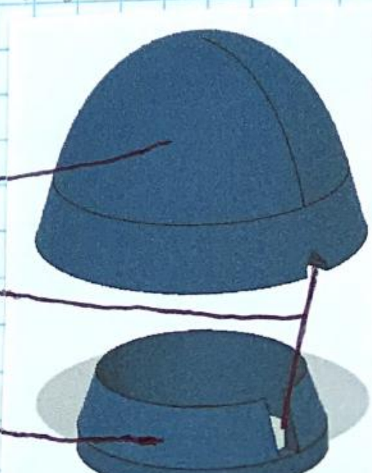
☆ Manufacture Parts - Why?

3D printing is extremely versatile and allows very complex geometric shapes to be printed easily. It also allows for rapid prototyping of parts

The thruster caps should decrease the drag from the frontal surface of the motors.

Thruster Caps





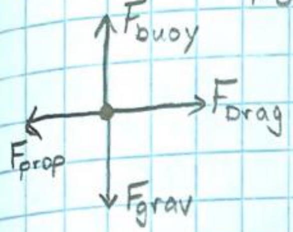
Hydrodynamics

<u>Objective:</u> Optimize our hydrodynamics to reduce drag, which will help us improve our speed while traveling through water

<u>Physics:</u>

$$F_{buoy} = m_{fluid}\, g = \rho_{fluid} V_{ROV}\, g$$

Net Force Diagram



For Neutrally Buoyant Robot: $F_{grav} = F_{buoy}$

$$m_{ROV}\, g = \rho_{fluid} V_{ROV}\, g \qquad m_{ROV} = \rho_{fluid} V_{ROV}$$

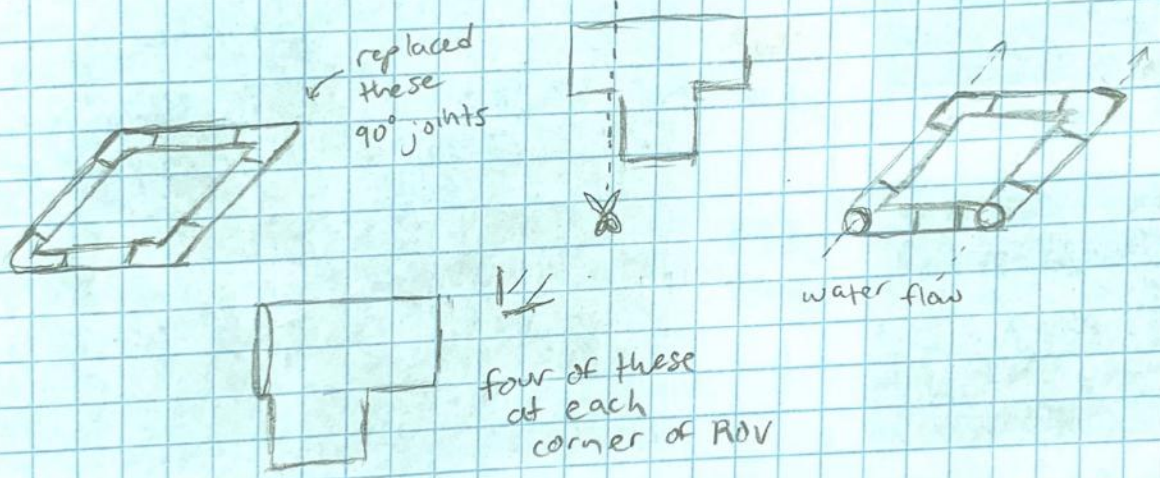
$$\rho_{ROV} = \frac{m_{ROV}}{V_{ROV}} = \rho_{fluid}$$

Therefore, the density of our ROV should be $1.00\ g/cm^3$

C_{Drag} = coefficient of drag

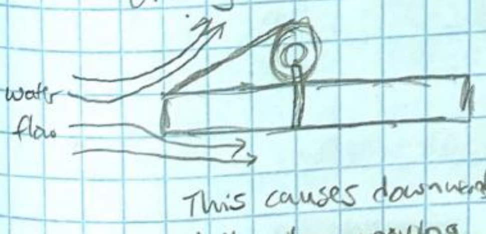
$$F_{Drag} = \frac{1}{2} C_{Drag}\, \rho_{fluid}\, v_{ROV}^2 A_{ROV} \qquad F_{prop} = m_{ROV} \frac{dv_{ROV}}{dt}$$

To minimize drag we minimize our front profile by drilling holes in the PVC Pipe and cut the T-shapes to create special corners



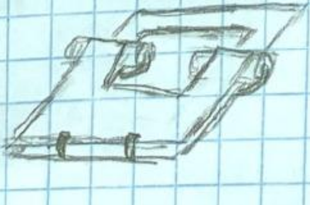
We also considered implementing a "windshield" on the front of our ROV, but we found that it increased our front profile and redirected the water upwards. These things caused our drag force to increase and our ROV to tilt downwards, according to Newton's Third Law of Motion.

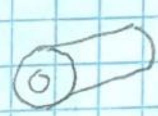
Orthagonal View



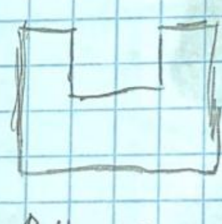
This causes downward tilt when moving forward

Perspective view





Used pool noodles for support and buoyancy



Used mesh and covered holes with duct tape

Both secured with zip ties

Drag Analysis

Objective: To learn about the drag force that slows down our ROV underwater.

Tasks: Since we had a CAD model of our ROV, we used a wind tunnel simulator called Autodesk Flow. This software showed us how a fluid (air in the simulator, but water in the competition) flows around our ROV as it travels at a constant speed.

This simulation visualizes the fluid flows around our ROV

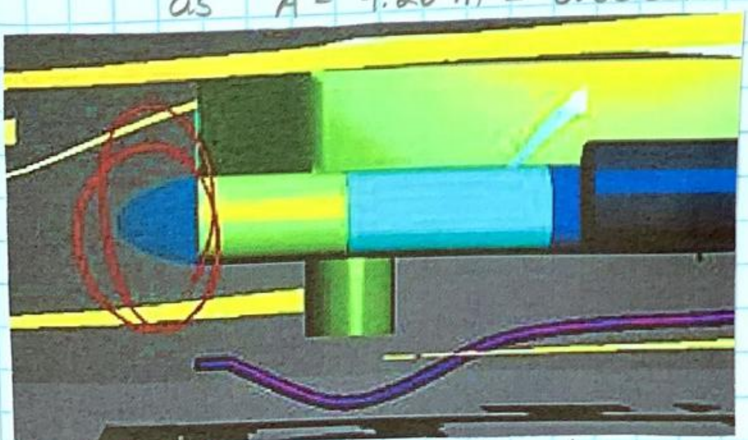
The software outputted our coefficient of drag (C_d), which is based only on the shape of our ROV, not the fluid it is in. $C_d = 0.93$

From our UNH times, we calculated our average speed to be:

$$v = \frac{472 \text{ in}}{55 \text{ sec}} \times \frac{2.45 \text{ cm}}{1 \text{ in}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 0.218 \text{ m/s}$$

$$\rho_{water} = 1.00 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$$ (Density of water)

The area of the front profile of the ROV was given by the software as $A = 9.26 \text{ in}^2 = 0.00597 \text{ m}^2$



Force of Drag: $F_D = \frac{1}{2} C_D \rho_{water} v^2 A$

$$= \frac{1}{2} \times 0.93 \times \frac{1000 \text{ kg}}{\text{m}^3} \times (0.218 \text{ m/s})^2 \times 0.00597 \text{ m}^2$$

$$= \boxed{0.132 \text{ N}}$$

This is not much, but adding a front cap (see graphic) would reduce our C_d and our F_d values.

This graphic shows the addition of a front cap, which would reduce our C_d value from 0.93 to 0.72. We may implement this later.

Cup Designs

Objective: To design a cup that can reliably activate the beacon

Tasks: 1) Draw and brainstorm cup designs
2) Build prototypes
3) CAD final build

Design Goals: • lightweight • easy to place • secure on ROV • lights beacon
• cheap • sturdy

Constraints: • Time • $25 Budget • Can't be too heavy

Designs:

Prototype 1:

Created by using one big cup upsidedown and using one smaller cup rightside up inside the big cup. Nuts a taped to the bottom to make it bottom heavy and the magnet is located at the yellow tape.
Pros: Small
Cons: Hard to put on, Magnet too weak

Prototype 2:

Created usin 1 solo cup and 2 small plastic cups, one inside and one on top. We used 4 pairs of magnets separated equally around the cup. There are 5 nuts taped at the bottom equally spaced. The top is wrapped with backer foam (~ 10 in)
Pros: Easy to put on and take off, Easy to manipulate
Cons: Big, Heavy

To strengthen our magnetic field inside the cup, we made the magnet pairs opposite of each other have different poles.

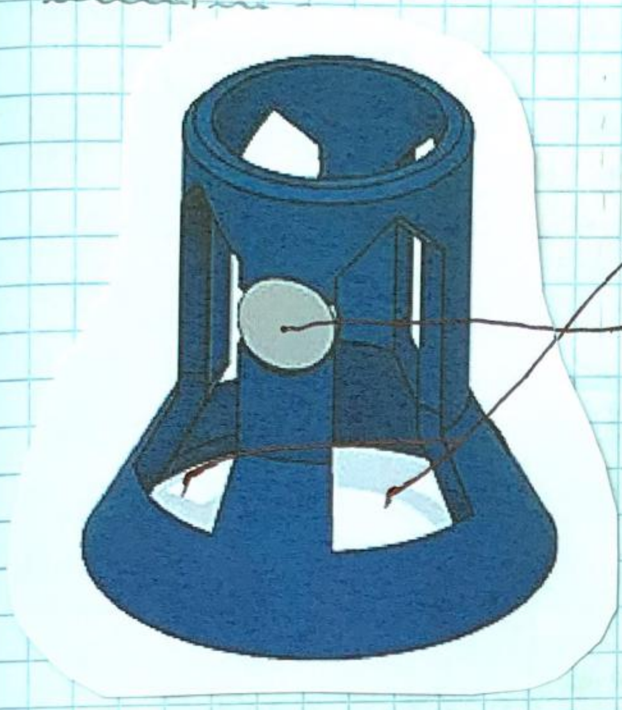
~ cup outside

Top View

Magnetic field passes through the center of the cup which is what causes the voltage difference in the beacon.

Cup Designs (cont.)

Prototype 3:



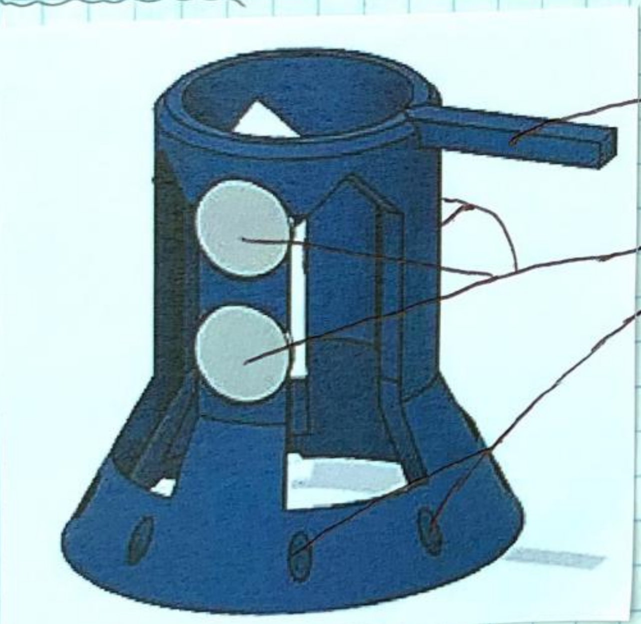
Created using 3D printing, featuring:

- close-fitting inner diameter to slide down the beacon
- 4 slots to reduce plastic use and reduce drag while falling
- countersunk magnets

Pros: cheap, custom-designed and complex
Cons: takes long to print, hard to rotate around beacon, magnet range and strength limitted, no easy way to add additional mass

Not printed due to abundance of cons in favor of a redesign

Prototype 4:



Created using 3D printing, featuring the following revisions from Prototype 3:

- arm to allow easy rotation around the beacon
- 2 countersunk magnets on each side
- holes for zipties to attach additional mass

Pros: many features, cheap, optimized
Cons: must be printed in two parts, takes long to print

Prototype 4, printed and without arm

Mass - 24 grams
Cost - $1.20

Observations

- UNUSUALLY LIGHT
- surprisingly rigid
- magnets fit in snuggly
- ziptie holes seem a bit too small

Testing at Greater Lawrence Tech HS

objective: To enhance driver practice and adjust ROV according to peformance

Tasks:
1) set up course underwater
2) Test Robot and observe
3) Modify ROV

Testing Procedure: Obstacle Course
1) What needs testing: Speed/time through course
2) Experiment: Time down and back times with stopwatch

Challenge Course
1) What needs testing: how easy picking up objects are, how easy dropping objects into cups are, strategy, beacon lighting.
2) Experiment: Drive ROV to manipulate each object and place them onto premade platforms. Also test cups on beacon.

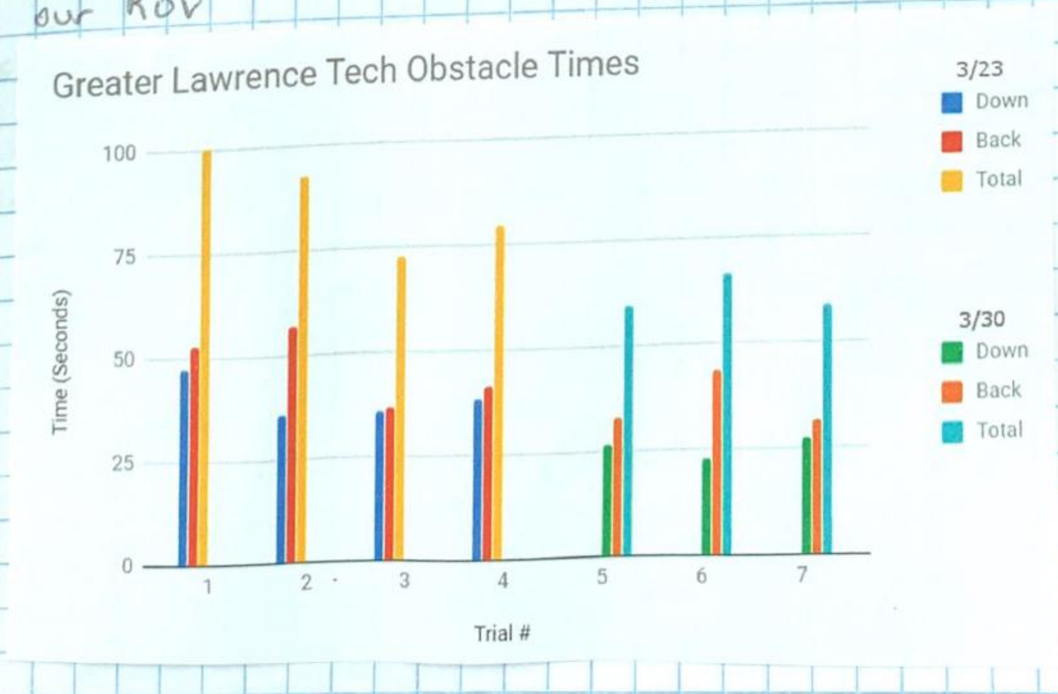
Testing Limitations:
- Beacon did not have electronics assembled
- platforms and cups weren't raised
- no hoops for challenge course

Issues & Solutions:
- Visibility underwater with the refraction and reflection of light makes it hard to see
  - solved by bending knees to lower head and move the reflection
- Left motor was severely weaker than right motor
  - remade a motor and re-soldered it onto our ROV

Testing Results:

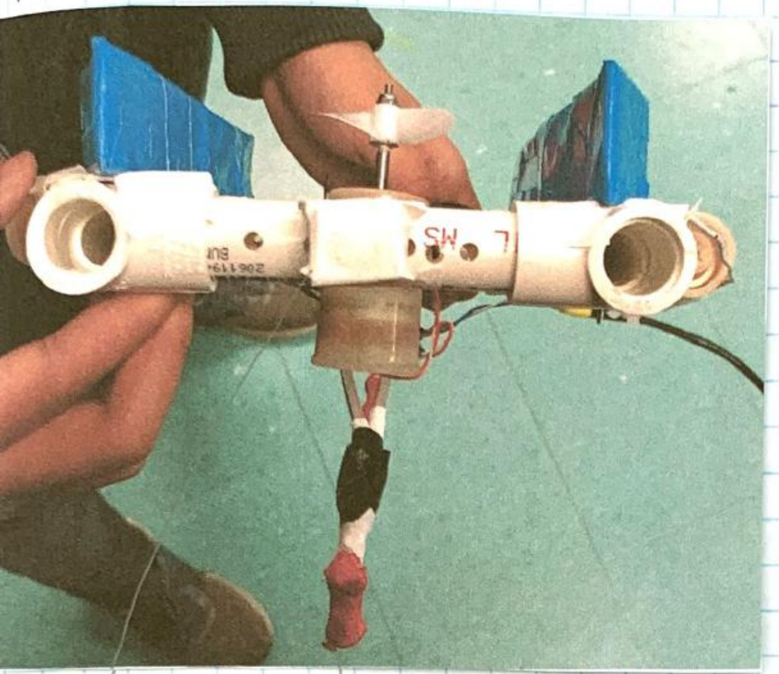
Trial #	Down (s)	Back (s)	Total (s)
1	47.27	53	100.27
2	35.69	56.85	92.57
3	35.93	36.79	72.72
4	38.57	41.13	79.7
5	26.62	32.89	59.51
6	22.64	43.62	66.26
7	27.41	31.48	58.89

Results show that more practice improves our time in the obstacle

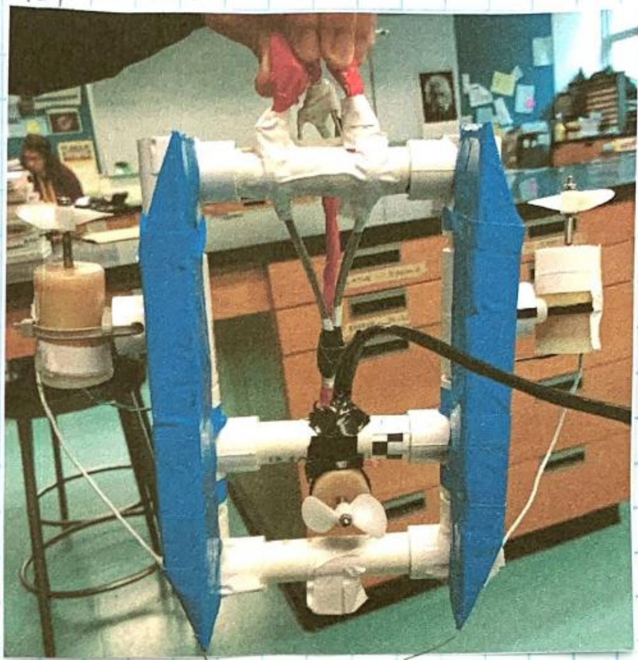


Current Design Photos

Front View:



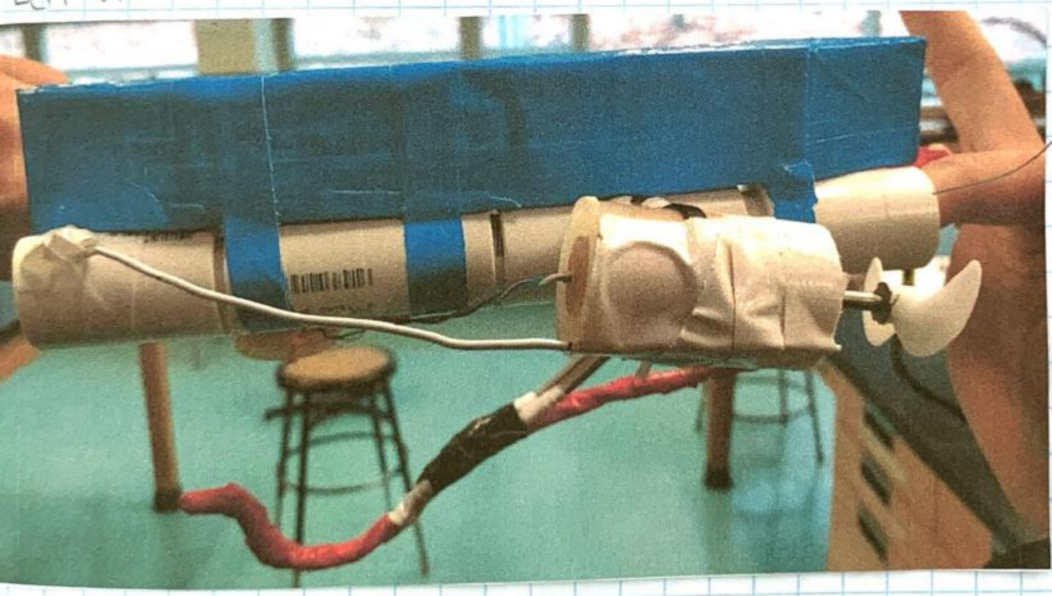
Top View:



magnets hook floats

We placed magnets on the front profile to hold our cup by the magnets

Left View



On the PVC here we rotate our hook so that we don't get caught in the obstacle course and also start further from the wall. Our hook rotated this way in addition to our ROV body and front magnet barely fit within the 18" restriction.

UNH Regionals:

With this design we were able to place as runner-ups overall, and first place for the challenge course.

__Obstacle times:__ First run 1 min 2 seconds, Second run 55 seconds

__Challenge Scores:__ Got all balls in cups, tapped beacon light to temporarily light it, got all ROV pieces, 12 minutes 47 seconds total

$\boxed{\text{37 pts / 45 pts}}$

At this time we used cup prototype 2 which couldn't light the beacon so we used the magnets on our ROV to temporarily light the beacon.

Future ROV Redesigns

Objective: Design and prototype ideas for nationals competition

Tasks:
1) Discuss current issues and possible solutions
2) Draw/CAD our new designs
3) Prototype designs

Design Goals: • lighter • thinner • maintain rotating hook

Constraints: • $25 budget • 18"x18" size • Fully completed by June 1st

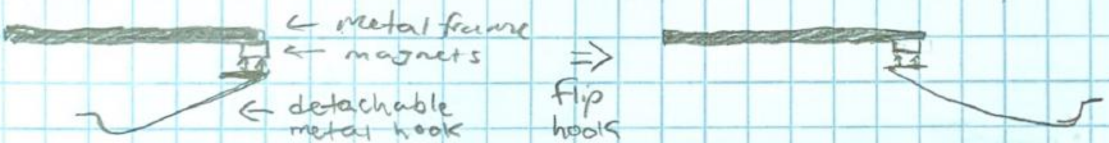
Designs:

Change to a metal frame:

The frame comes from a campaign sign, already welded but we cut it. This is a lot lighter and thinner than PVC. However, we predict buoyancy issues when picking up objects since lighter ROV's will have a greater shift in weight. The thin frame also makes it more difficult to attatch parts like the motors.

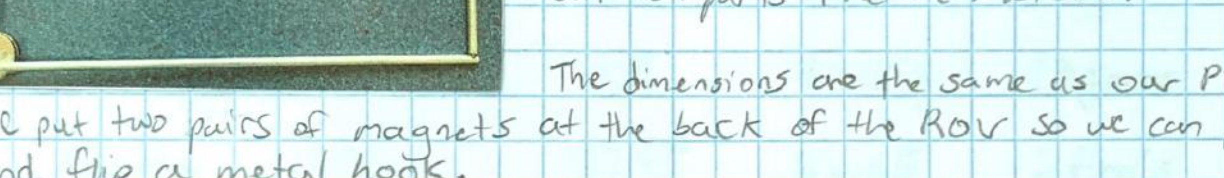
The dimensions are the same as our PVC frame

We put two pairs of magnets at the back of the ROV so we can place and flip a metal hook.



We also plan to put on thruster caps for our motors so that they are more hydrodynamic. They are demonstrated in our CAD section of our engineering notebook (pg 10)

We are currently having difficulty creating a new metal hook for this metal frame design because the two rods we are using don't stick well together



We were hoping to slide rod 1 into here and glue the rods together at this point but it is a little unstable so we need to come up with a new way to connect the rods, maybe better adhesives.

Budget

Item Name	Quantity in Package	Cost of Package	Unit Cost	Amount Used	Cost for Item
1) Metal Hangers	12 Hangers	$7.99	$0.67	4 Hangers	$2.66
2) 3D Print Spool	1 Spool	$1.00	$1.00	1 Spool	$1.00
3) Zipties	100 Zipties	$5.98	$0.06	15 Zipties	$0.90
4) Duct Tape	55 meters	$3.46	$0.06/m	20ft	$0.38
5) Magnets	80 magnets	$10.90	$0.14	9 magnets	$1.23
6) Clear Plastic Cups	50 cups	$4.25	$0.09	2 Cups	$0.17
7) Solo Cup	50 Cups	$3.78	$0.08	1 Cup	$0.08
8) Backer Foam	20 ft	$4.96	$0.25/ft	10 inches	$0.21
9) Metal Nuts	100 Nuts	$3.14	$0.31	5 Nuts	$1.57
10) 3D Printed Cups	N/A	N/A	$0.05/g	23 grams	$1.15
11) Swim Flotation Belt	3 floats	$7.95	$2.65	2 floats	$5.30

Total: $14.65

Money Remaining: $25 - $14.65 = $10.35

References

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