Individual logbook IGEN 230 - Team 11

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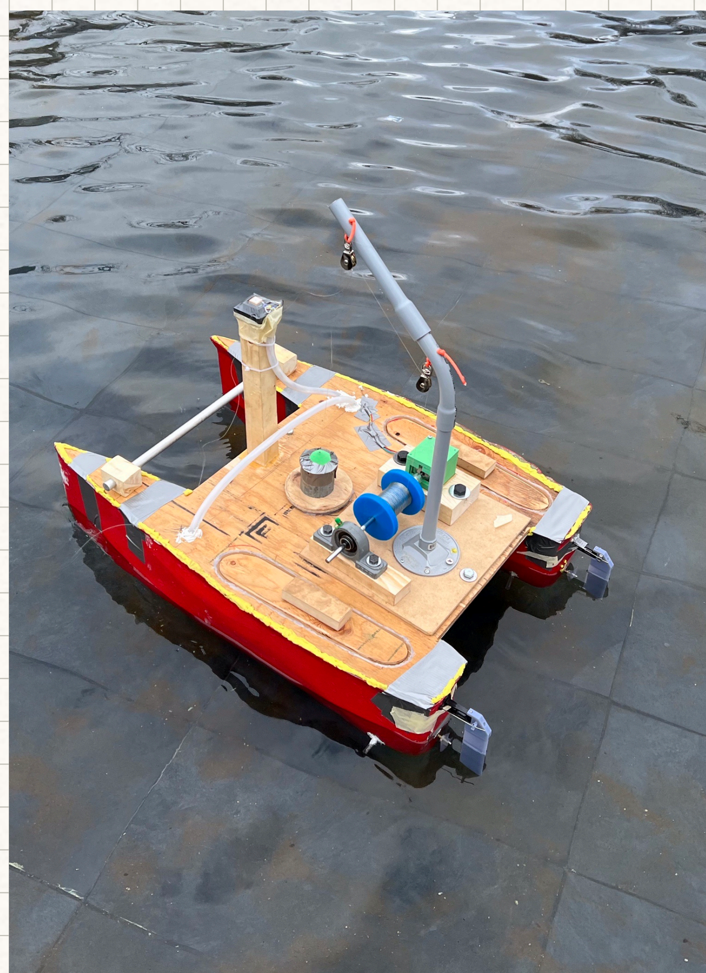
Design & Developement of the Hull



13 Jan 2021

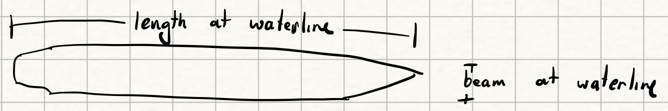
Research Catamaran

Source: Catamaran Design: Hull shape | Essential Catamaran Knowledge Ep. 1 (youtube)

Ideal catamaran Hull design

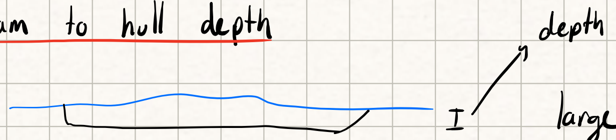
length to beam ratio

(important only for performance cat not crusing cat)



• narrower hull, better performance

beam to hull depth



more depth => more drag

large beam => deep hull
narrow beam => shallow hull

Crusing Cat =>
- large & deep hull
- Increased displacement
- More wetted surface area
- Hull entry angle open
- More confort & interior volume

Slenderness ratio

water displacement

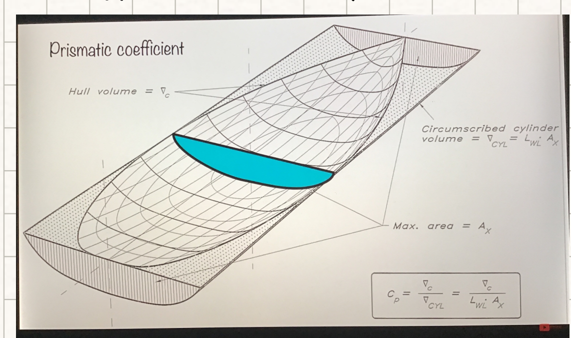
$\frac{\text{Hull Volume}}{\text{Length}}$ above 7 for performance cat

drops for crusing cat as low as 4

=> [more comonly used is hull waterline length / hull waterline beam ratio (LWL/BWL). For cruising cats 10:1 is a good ratio, however, heavier ones can have up to 2:1]

Prismatic coefficent

measures fullness of hull



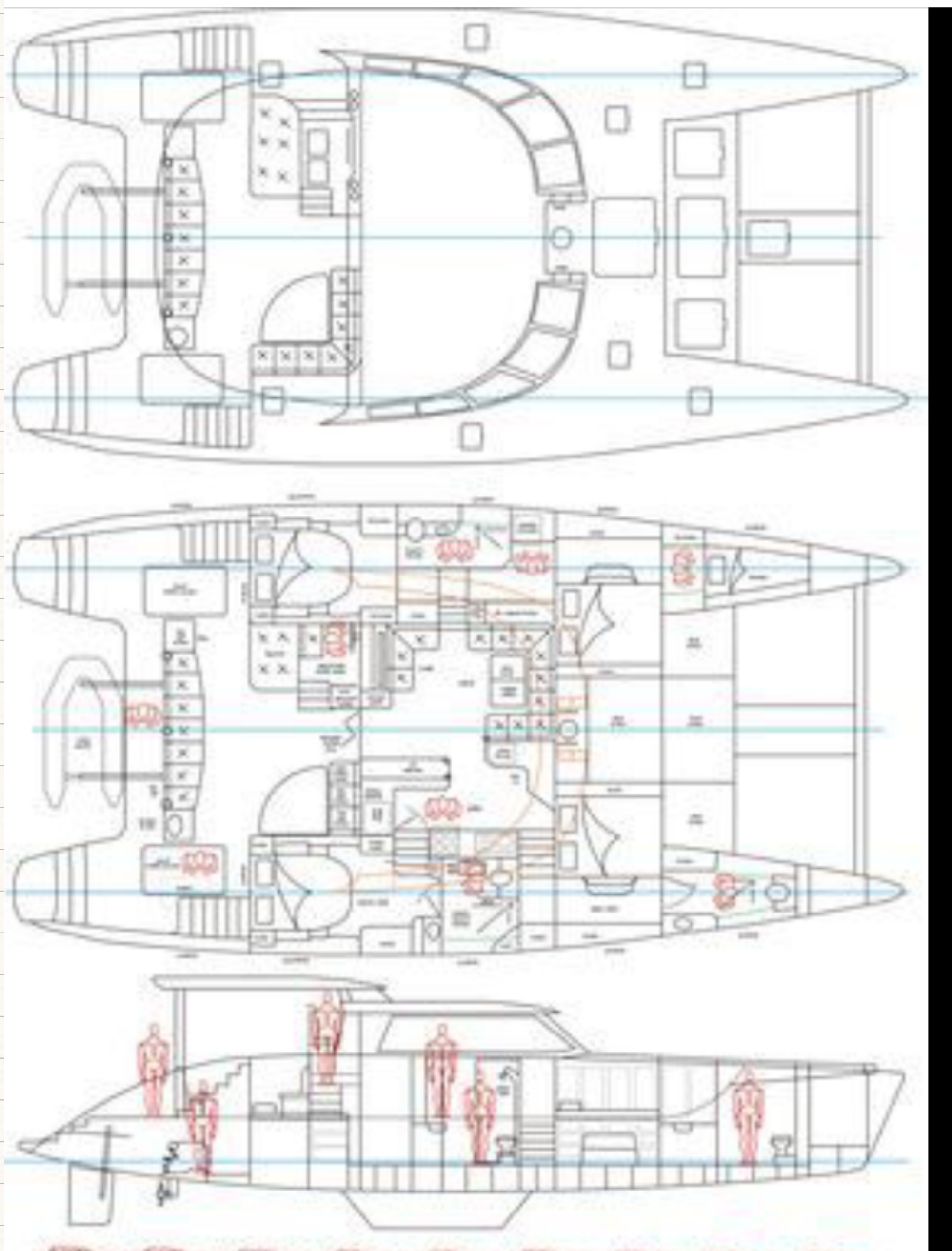
Distance between two hulls -> larger better (less interferance between waves)
interhull distance

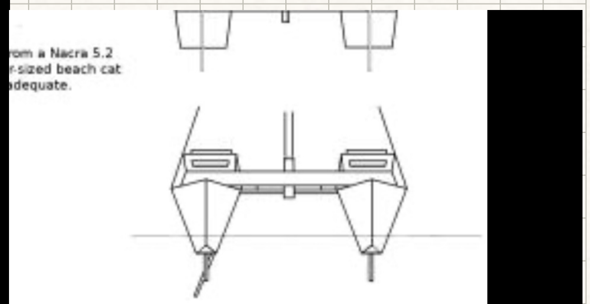
flat vs round

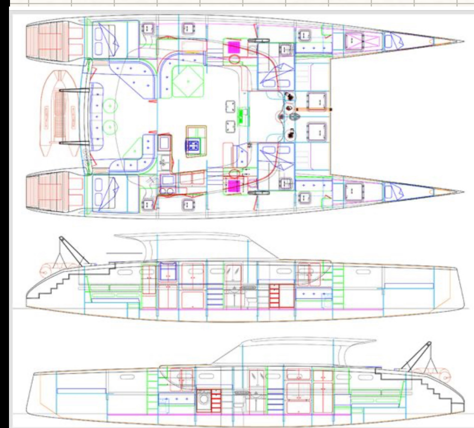
flatter hull creates lift while at speed increasing peformance

Jan 22nd

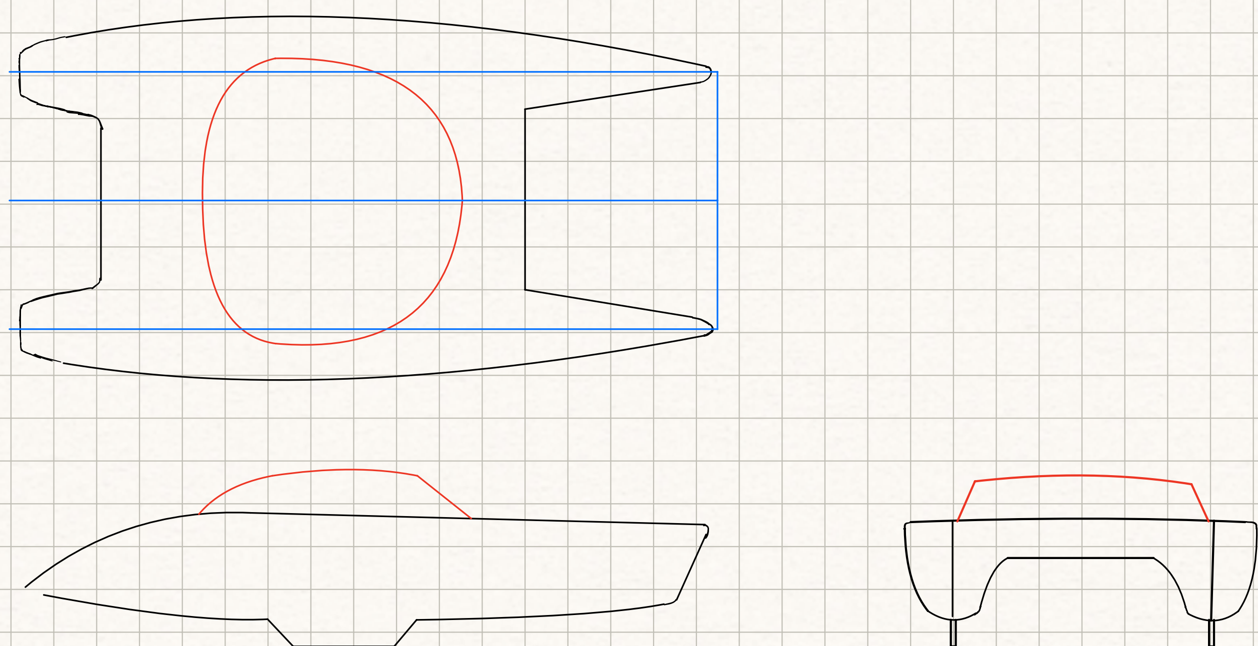
Provisional design for crusing catamaran







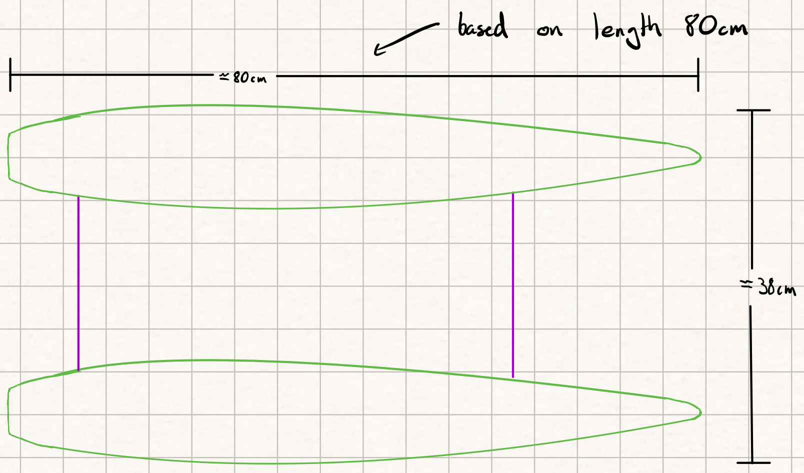
Preliminary Cat design 1

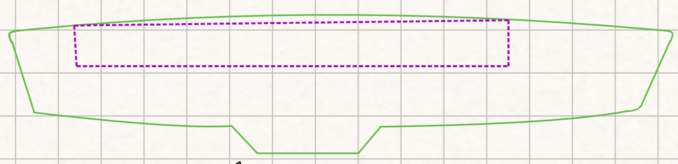


Jan 26th

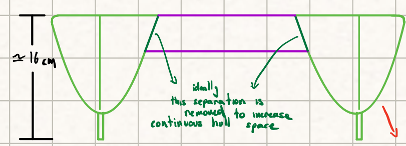
Cat design 2

(easier to manufacture out of sheet metal)





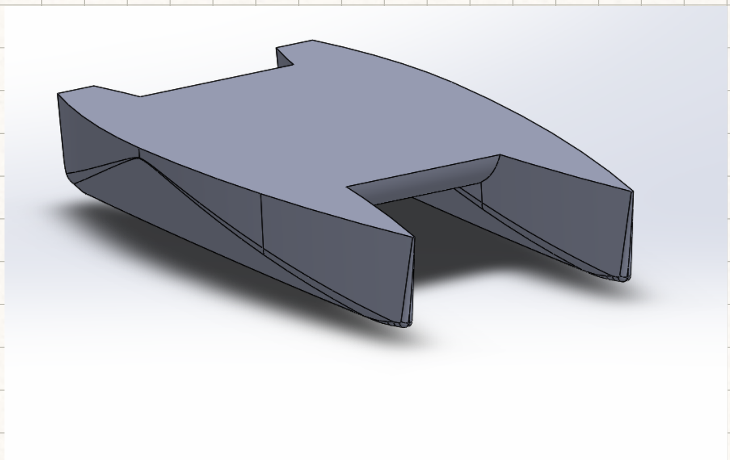
mini keels are optional
but ideal for improved
performance in rough waters

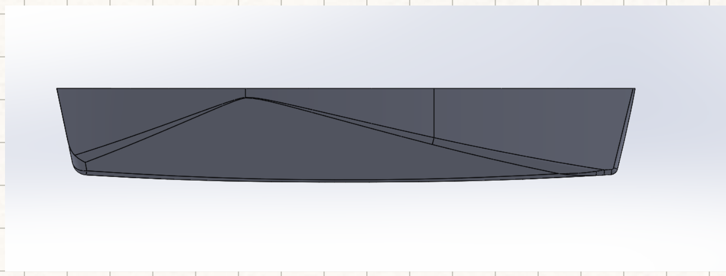


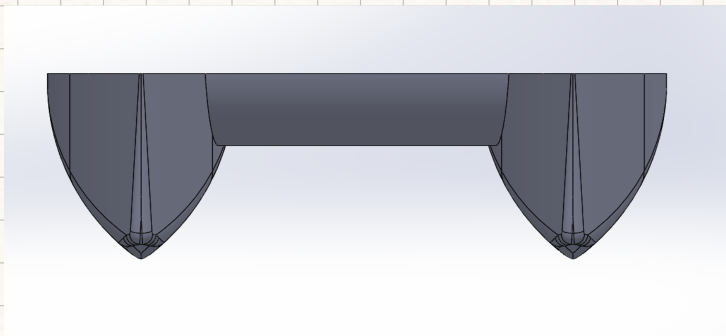
ideally flatter bottom
e.i. ∪ instead of U
depending on difficulty

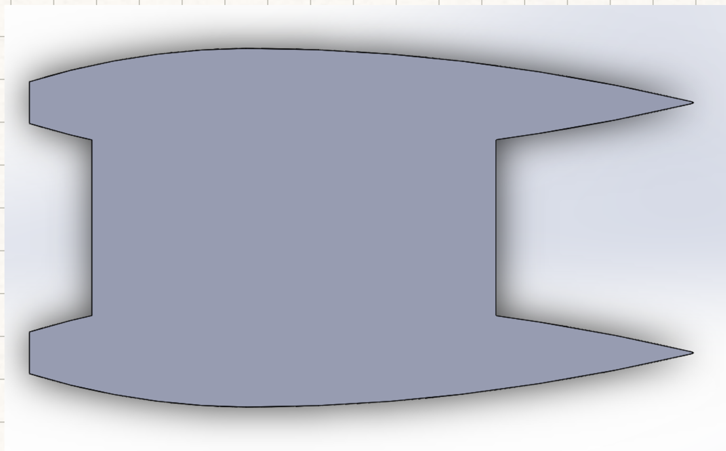
Jan 28 - Feb 2

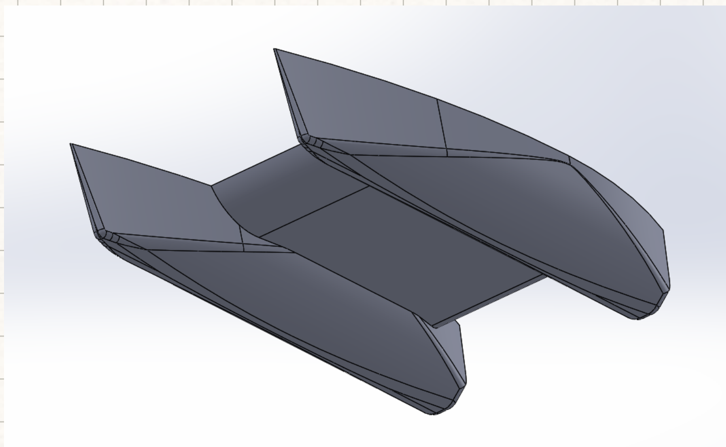
SolidWorks Model Cat V1











Surface area 5194.23 cm^2 ≈ 0.519423 m^2

79.7 cm length

43 cm width

12 cm height

Total load of boat

$0.5194\,m^2$ surface area $\simeq 0.65\,m^2$ (over estimate)

$0.65\,m^2 \times 0.0025$ thick sheet $\simeq 0.004875\,m^3$ of aluminium

$\Rightarrow 0.004875\,\rho_{Aluminum}$

mass of aluminium hull $= 4.3875$ kg

ave ρ of aluminium* $= 2700\,kg/m^3$

12.5 - 15 kg of components $\Rightarrow$ 15 kg

estimated deck 0.5 kg $\Rightarrow$ 1.5 kg

$$W = \rho_w \cdot g \cdot V_{submerged\ hull}$$

$$\frac{(4.875 + 15 + 1.5) \cdot g}{\rho_w \cdot g} = V_{submerged\ hull}$$

$$V_{submerged}\ hull = 0.021375\,m^3$$

Feb 9

After getting the cat V1 3d printed at 0.25 scale, we realized that it didn't displace enough water (can't sustain enough weight). I have to design a V2 of the cat increasing the individual size of the hulls, both width and height. Lastly we decided to design the hull to be used in fresh water. From research, s.g. of tailings ponds is 2.6 - 3.35 (www.fhwa.dot.gov). This would change the design completely. Since we can't test in those conditions, we will design for freshwater as this will mostly be a proof of concept.

While in the shop, we got the advice from Zach (ign shop manager) to make hull out of fiberglass. This would not only be easier than sheet metal, but also free as ign provides the materials for fiberglassing. It will require a negative mold.

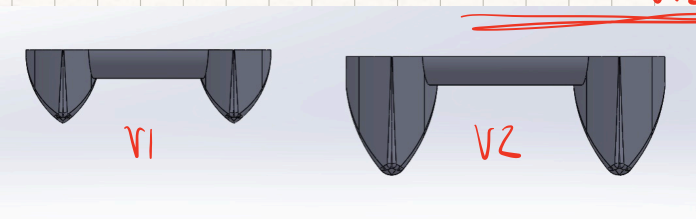
* The world material.com

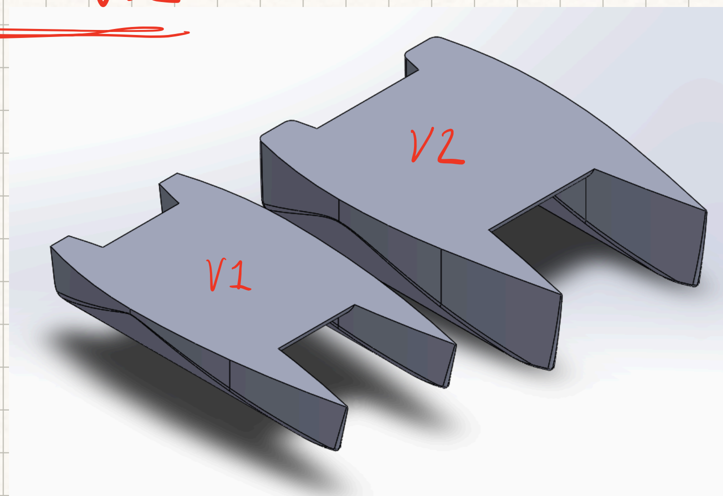
Feb 11 - 17

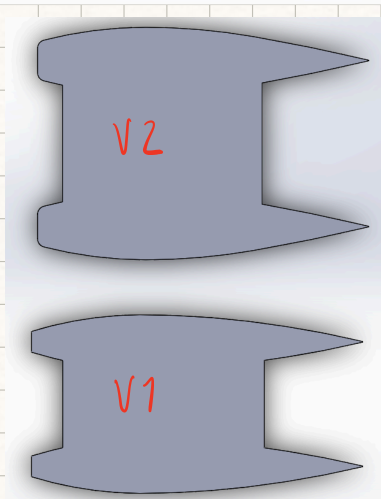
I finished V2 of the cat. This time I managed to calculate the volume using solidworks as well as the depth of hull in the water with respect to weight.

flowing are screenshots of V1 v.s. V2, the cat V2 alone, weight Vs depth screen-shots.

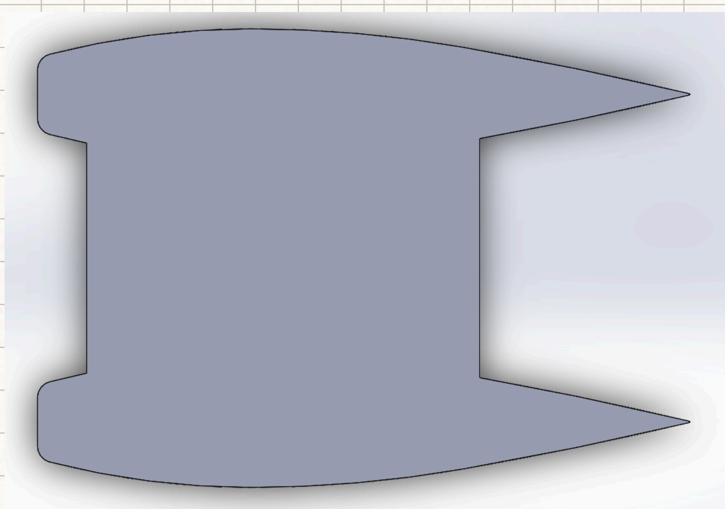
V.1 V.S V.2

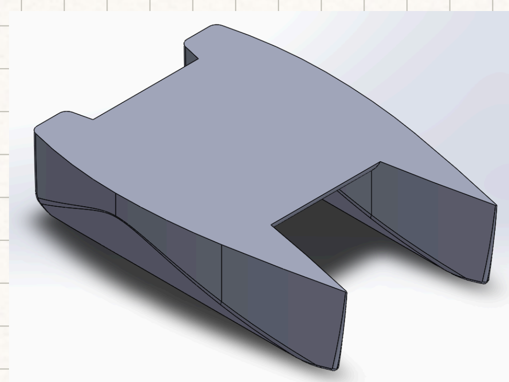


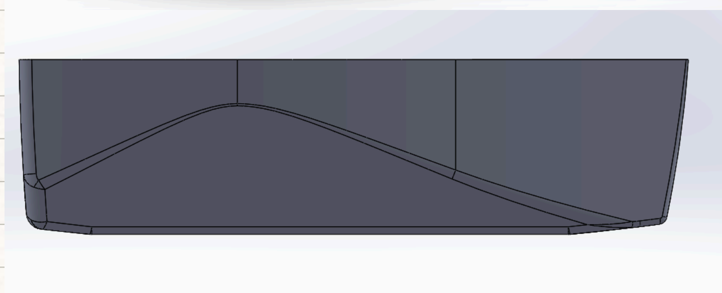


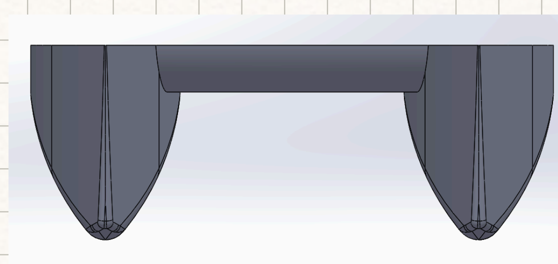


V2









Calculations for buoyancy for V2 hull

Mass components on boat (max)		15 kg
Upper deck	(estimate)	2 kg
Hull weight *		negligable
		17 kg

$$W = \rho_w \cdot g \cdot V_{submerged\ hull}$$

fresh water

$$V_{S.H.} = \frac{17 \cdot g}{\rho_w \cdot g} = 0.017\ m^3$$

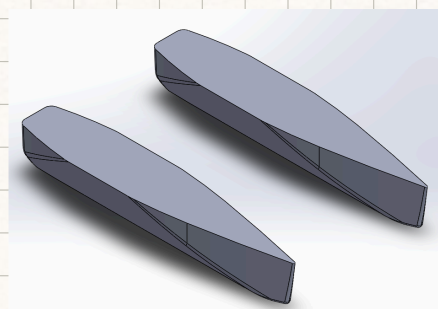
Salt water

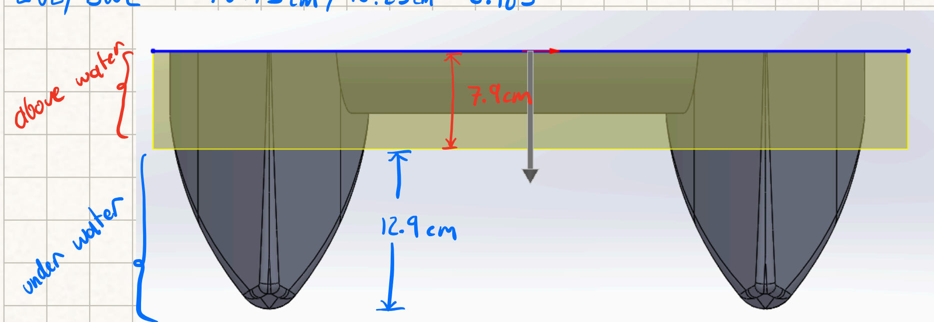
$$V_{S.H.} = \frac{17 \cdot g}{S_{sw} \rho_w \cdot g} = 0.01657\ m^3$$

depth of hull in water with different loads (mass)

mass: 17.06 kg , $V_{submerged} = 0.01706\ m^3$

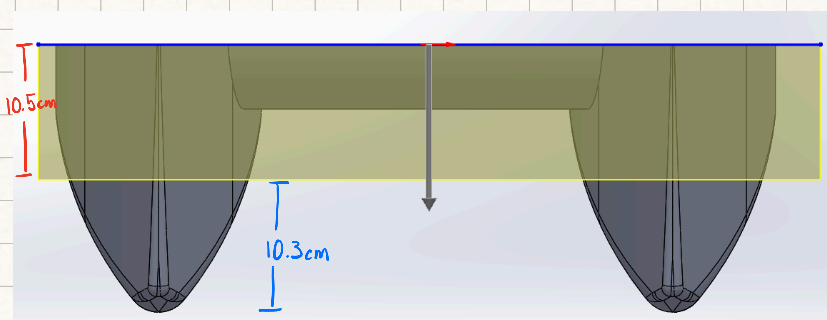
LWL / BWL = 78.73 cm / 15.25 cm = 5.163





mass = 12.4 kg $V_{submerged} = 0.0124\ m^3$

LWL / BWL = 78.26 cm / 13.96 cm = 5.606



This range (17 kg - 12kg) is the ideal operating range, however, it can be used with max 19kg. No min as more wieght can be added.

*

total S.A.		top S.A.		
11494.68 cm²	-	3030.06 cm²	=	8467.62 cm²

thickness → estimate.

$8467.62\ cm^2 \times 0.5\ cm = 4234\ cm^3 = 0.004234\ m^3$

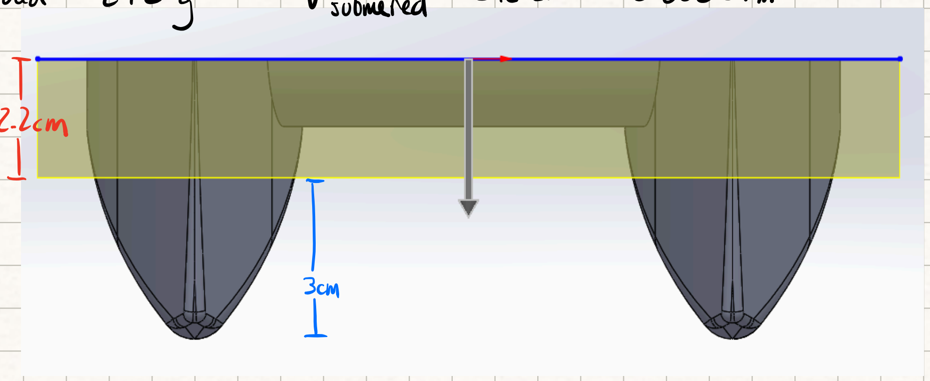
$0.004234 m^3 \times 1.7^{*} kg/m^3 = 0.007198\ kg$

* average $\rho_{fiberglass} = 1.7\ kg/m^3$

Buoyancy Verification with scale model

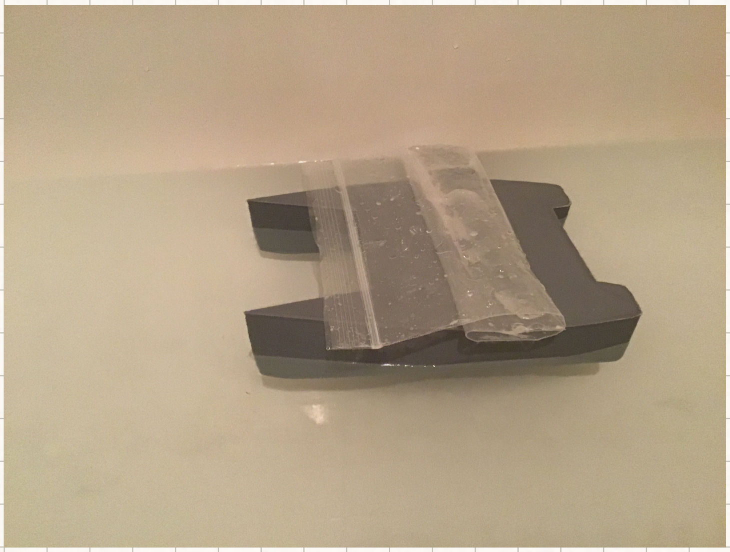
Testing to see whether the calculations on buoyancy are accurate is important in order to prove that the boat would handle the load we planned to put on it. To do this I 3d printed a model scaled down to 0.25 of the original. The model itself weighs 182 grams. Adding 60 ml (1/4 cup) of water in a plastic bag will make the total weight 242 grams,* equivalent to 15.5 kg on the real size model. To see if it's accurate, on the cad model of the scaled down version I'll calculate theoretical depth of hull and then measure what depth it went to. If it's close enough then we can safely assume the real hull will bare the weight that was calculated above in page 8. Since the models weight is distributed unevenly between the bow and the stern, not all points will be submerged equally. That's why the reading will be taken at the midpoint of the boat

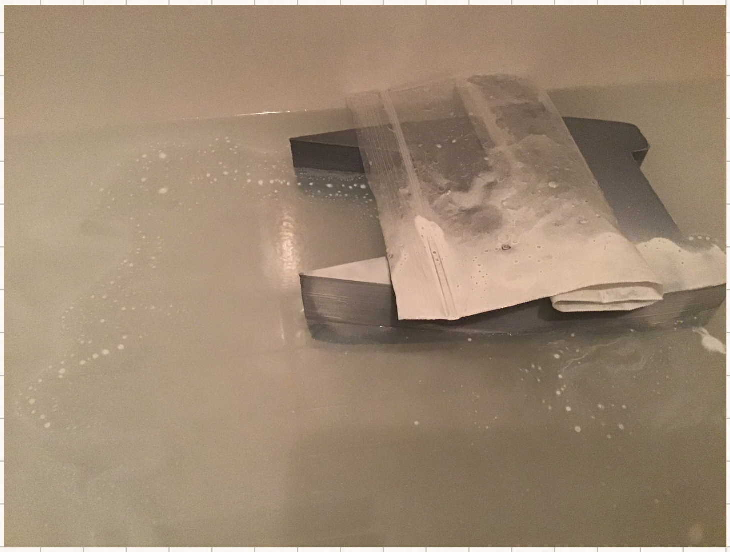
load 242 g $\quad \forall_{submerged} = 240\ cm^3 = 0.00024\ m^3$

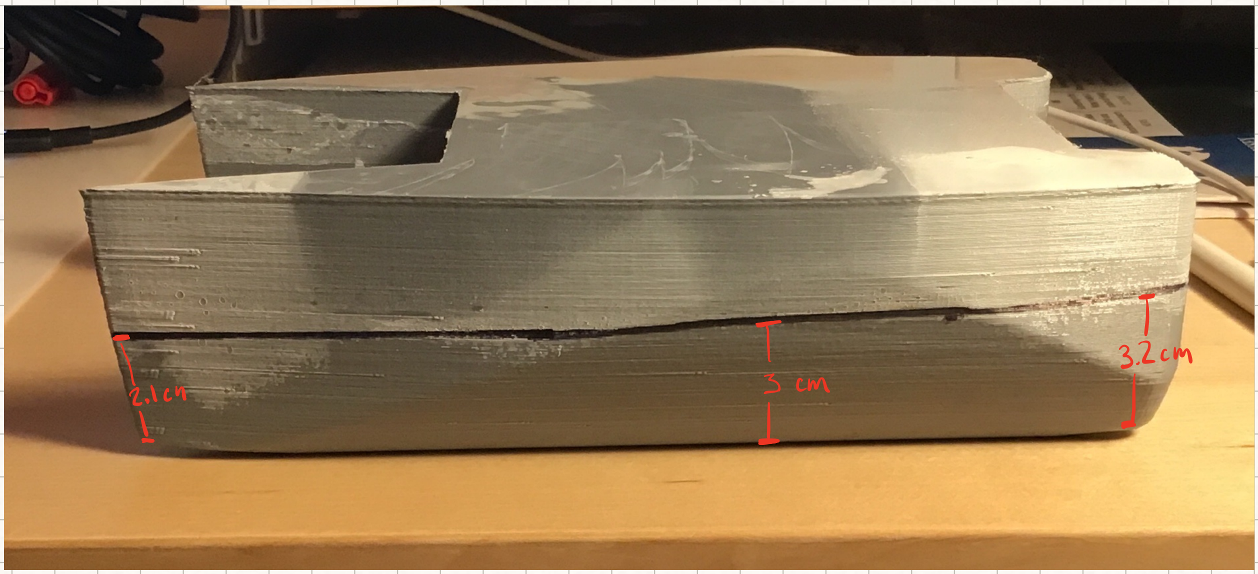


$* \ 0.242\ kg \times 4^3 = 15.488\ kg$

To measure the depth I spray painted the boat while in the water. Once out of the water I could measure up to the point where the paint started.







Overall this helps us comfortably say that the real sized hull will support the load that has been calculated in page 8. Regarding the waterline of the prototype, since this it had the weight equally distributed with respect to volume, its likely that in the actual full-scale boat will have the mass equally distributed between the stern and the bow. Even if the natural design and weight of the components within the hulls don't provide a steady weight distribution, the hulls can be weighed down using ballasts.

Feb 28th

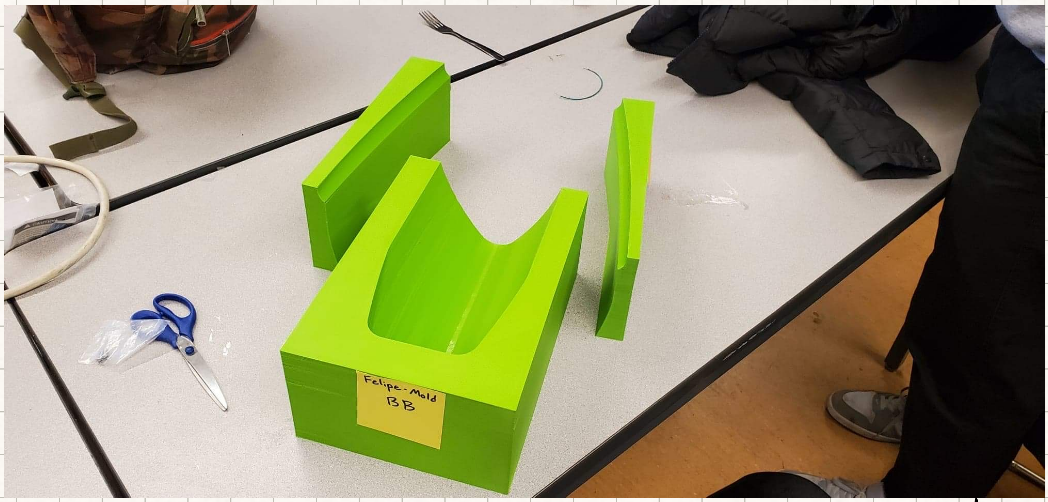
Negative hull for fiberglassing

Once the team agreed on the final design, I started looked for ways to create a negative mold in order to fabricate the hull out of fiberglass. Initially, we were looking into pink insulation foam. However, this was too expensive to buy considering our limited budget. It was also hard to source it on campus from other projects/ teams that discarded it. I did some research and asked Marvin (3D printing manager) as well as Zach (Igen shop manager) if this was feasible. Once I got the heads up from them, I 3d printed a negative mold (of the whole hull) made out of multiple pieces. The pieces were as big as the biggest printer could fit. Once the first piece was printed, we realized that the build was too weak and there were too many imperfections in the model for fiberglassing. Additionally, the whole print would take too long for our timeline.

March 7th

Printing Negative hull + sanding

After seeing the poor build quality and print time for the whole hull print, my team and I agreed to make two identical fiberglass hulls out of the same 3D printed mold. This idea would eliminate the need to make the bridge, between the two hulls, out of fiberglass. This will also cut down the printing time significantly. Lastly, to improve the quality of the mold, the pieces weren't printed as big as the machine could fit. Instead, I submitted for print, pieces half that size.



First parts that were printed and sanded

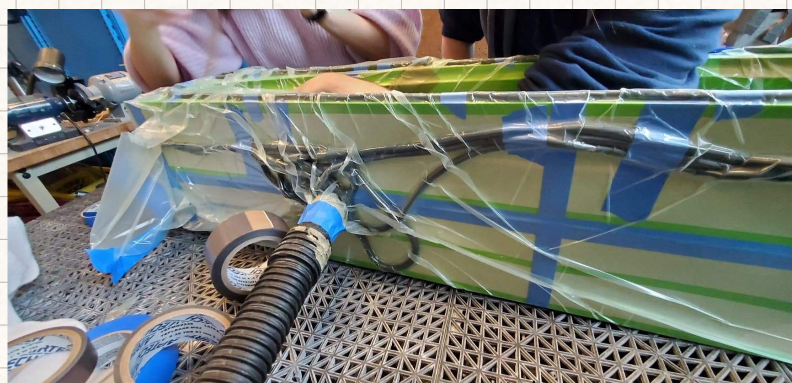
After picking up the first printed parts, I hand sanded them down, so that when we fiberglass, the hulls will come out as smooth as possible. This increases the quality of the fiberglass. This was a time-consuming process as I was trying to achieve the smoothest surface possible and imperfections in the print made it hard. I also did this all by hand (instead of using a sander) to avoid heating the PLA too much to the point where it melts.

March 15th

fiberglassing hulls!

With the help of my team, we sanded all the pieces to fiberglass the hulls. At the shop I hot glued & taped the pieces together. We went to the EDC with Zach and 2 team members (Clara and Triss) to fiberglass the hulls. To remove the fiberglass from the hulls we used thin plastic made a plastic bag around the mold (instead of mold release), then vacuuming it to the mold (this took many iterations of the 'plastic bag technique', until we got a proper vacuum in the whole bag). Despite trying hard to remove the creases in the plastic, we didn't manage to get them all. In order to be able to make the two molds in one day, we used a higher catalyst to resin ratio for the first hull so that the curing time was faster. This had a side effect that the exothermic reaction released more heat in a shorter time frame. By the time we were finishing applying the fiberglass and the resin, we could tell that the mold was starting to deform, especially where the different 3d printed pieces met. This then complicated the fabrication of the second hull. We used the same technique with the plastic bag, this time there were more bumps and creases in the plastic due to the deformed mold. Overall, the process went well for the first-time fabricating something out of fiberglass. However, there are many improvements I can come up with, which can be implemented next time I do something similar.

Top and bottom half of mold before hot gluing them together

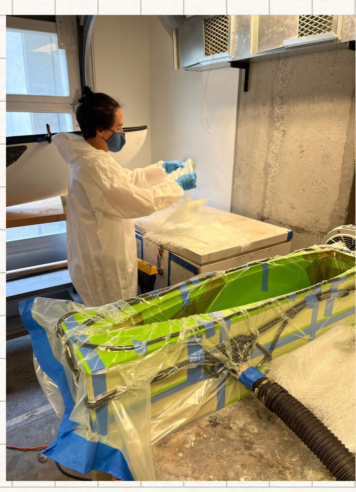


Plastic bag around mold w/ vacum

removing creases in the plastic

deformed hull after fiberglassing first hull

cutting fiberglass just before applying it to the mold.



first hull right after it was pulled out of the mold.

March 17th

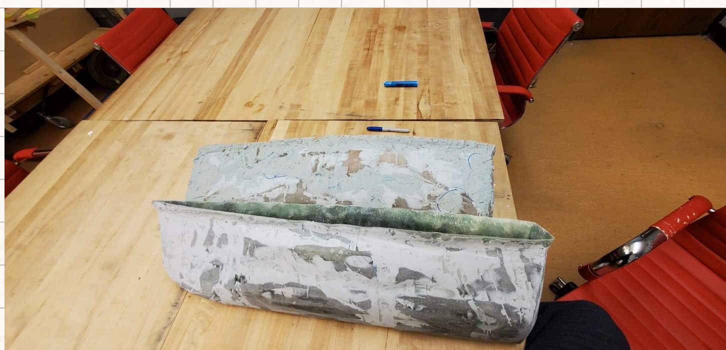
Cutting excess fiberglass + sanding & filling for the first time

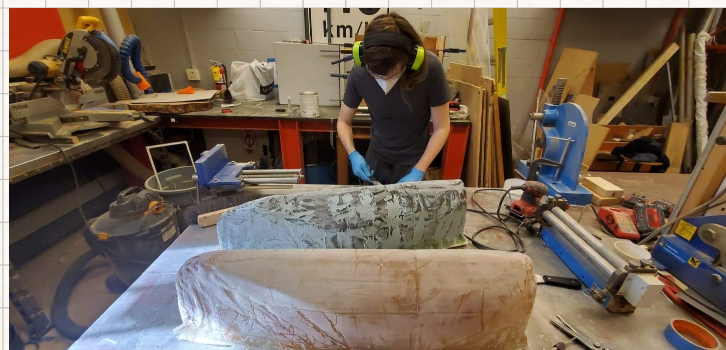
Having both hulls, first thing I did was cut off any excess fiberglass with metal scissors. I cut as close to the edge of the hull where there was no cured resin on the fiberglass (the hulls still had a lip that will have to be cut of with an angle grinder). After this, I sanded down the hulls and all the cavities that the plastic left. Afterwards, I used a filler to fill all the holes and make sure the shape of the hull was the one we wanted.

Using filler to patch holes and cavities as well as giving the hulls the desired shape

More filling & sanding + fitting deck + spray painting

This process was much more time consuming than initially expected, I probably filled and sanded each hull about 6-8 times. This was a consequence of the mistakes made while fiberglassing the hull. After finally finishing the tedious process of filling and sanding, I spray painted both hulls red. I made the mistake of painting the hulls before testing them for leaks. I was confident that the 8 times filling would've covered any holes, I was proved wrong as the were pockets of air in the fiberglass which were letting the water seep in. In the middle of the sanding and filling, I used the angle grinder to cut the edges of the hull and gave it a flush finish. I also sanded the deck to fit on top of the hulls so that It would sit comfortable in the hull.

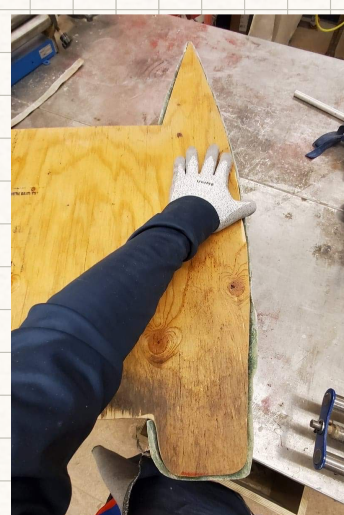




filling the hulls

Sanding the hull

Spray painted hull



Sanded deck fit on the hulls

March 28th - 30th

Sealing leaks + cutting sheet metal bridge + helping with other tasks

I sealed the leaks coming from the hulls with even more filler, and makeshift a fiberglass-epoxy combo. After this was complete, I cut aluminum sheet metal that would be bolted onto the deck and would increase the structural rigidity of the bridge between the two hulls. I used the angle grinder to cut and sand the sheet metal. In between all these tasks I also helped drill the holes on the deck and the sheet metal. These were then used to mount the winch and for the sensor to drop between the hulls. Finally, in the last few days before the project video was due, I helped wherever the team needed me. I helped mount the motor and install the final touches to the boat including the 'tower' for the gps and the tubing for the cables to pass between hulls.

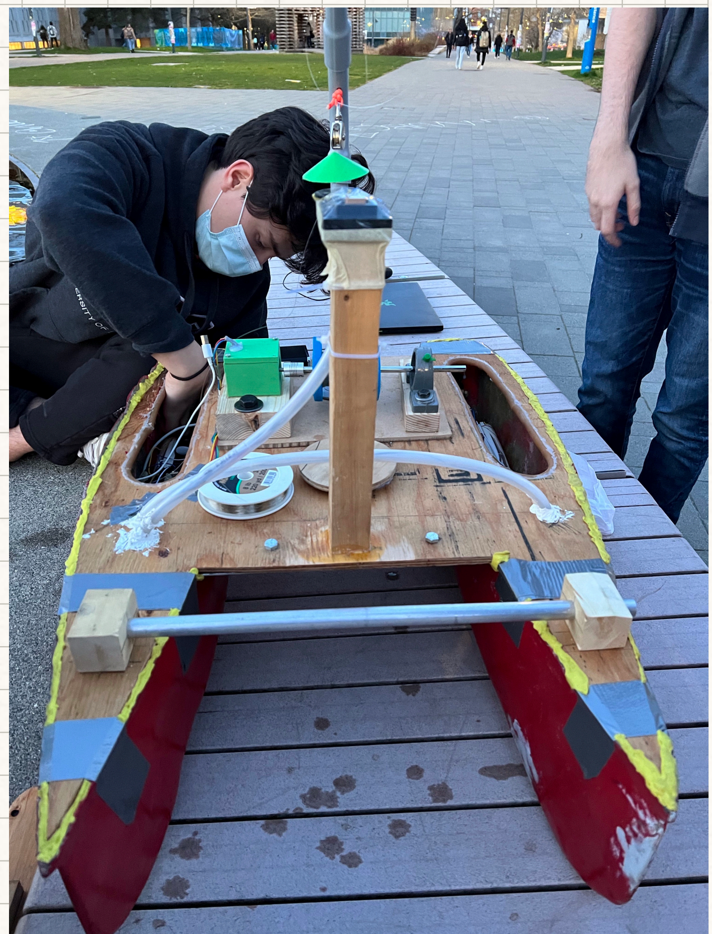
Mounting the deck, passing wires through the pipes, installing all electronics.

March 31st & Febuary 1st

Testing

We tested the boat twice in the UBC fountain. First time we tested for stability, leaks (prone due to the holes drilled for the propeller shaft), and weight distribution. This time around we couldn't get the electronics to work as the SD card in the Pi (the computer controlling the main functions of the boat) had been broken when installing it into the boat. The second time over we tested all functions except for autonomy in the fountain. 3 team members then went to a pond nearby to test the autonomous functions of the boat

Tying fishingline to the boat



Checking for leaks from the propeller shaft