ISOP ODS

ScopeQuality

PM

At the start of the group activity I clarified the tasks and completion times for each group member. Our beginning plan was to discuss the type of boat we wanted to build and complete the initial CAD model and first prototype from week 26 to week 28, and establishing communication between the two Arduino boards and setting up the control module and engine response within two weeks. In weeks 29 to 30 we plan to revise the CAD model as appropriate and confirm the final version, as well as finish designing and building the collector and motor and start building the final ship model. Finally, in weeks 31 and 32, we planned to complete all the work and test the ship. Although we did not follow this timeline exactly due to a variety of factors, but I would improvise and make new plans based on the actual situation and ultimately ensure we will have a completed boat at the end. During the manufacturing process, I always follow up on everyone’s task completion and organize group meetings to help members communicate effectively in order to better complete our ship. We have two types of group meetings: one involves entire team, while the other is for targeted members.

System Architect

Our rigorous testing regimen encompassed a comprehensive assessment of the boat’s structural integrity and operational performance.
Beginning with the water leakage test, we immersed the boat in water for 3.5 minutes and inspected the hull joints for any signs of water ingress. We found that all parts of the hull remained dry, indicating no leakage.
Then we have the load-bearing test, we placed the first prototype in water and applied heavy items(e.g. Tape) to confirm its maximum load capacity. We measured the weight of essential components such as the breadboard and motor, ensuring they were within the maximum load capacity.

During the stability test, we carefully observed the boat on the water surface to ensure the hull remained level and stable.
We also have the propeller rotation test, we assessed its performance both when separated from the boat and when mounted.We found that when the propeller was installed on the boat, it didn’t spin successfully because the voltage to power the motor was too low, so we add more batteries to ensure that the motor has enough voltage to spin.

Finally we have the conclusive water navigation test, we subjected the boat to real-world operational scenarios, successfully maneuvering it within a controlled pool environment.
Based on these experiments, we concluded that foam would be suitable as a flotation hull due to its lightweight nature, which enhances buoyancy.Also, we chose plastic for the main body of the boat because it’s naturally waterproof and durable, ensuring the boat’s longevity and resilience in water. Additionally, using lightweight plastic helps keep the boat’s weight down, making it easier to maneuver and more efficient during operation.

DesignBuild

Design Thesis

The design concept from the ground running for this project was **Data-Driven Design**. To achieve this, we approached the design from an optimisation problem point of view by setting constraints and optimisation variables while keeping some subjective firm decisions.

The reasoning to why we used this approach was to 'forget what a boat looks like' and see the task for the multivariable abstract problem that it is, with its many vague design decisions that would have to made.

Constraints

- Aggregated mass of all items
  (Motors, Power source, MCU, Materials)
  ↳ Height above water
    ↳ Gate Dimensions

$$B = \rho_f V g.$$

$$F_{\text{net}} = 0 = mg - \rho_f V_{\text{disp}} g$$

- Collection Object Dimensions
  ↳ Collection chamber dimensions
- Design Constraint Area
  ↳ General horizontal area of ship
    ↳ 420mm*297mm (250mm depth)
- Centre of Mass
  ↳ Location of components on ship, and their mass countermeasures.

Optimsation

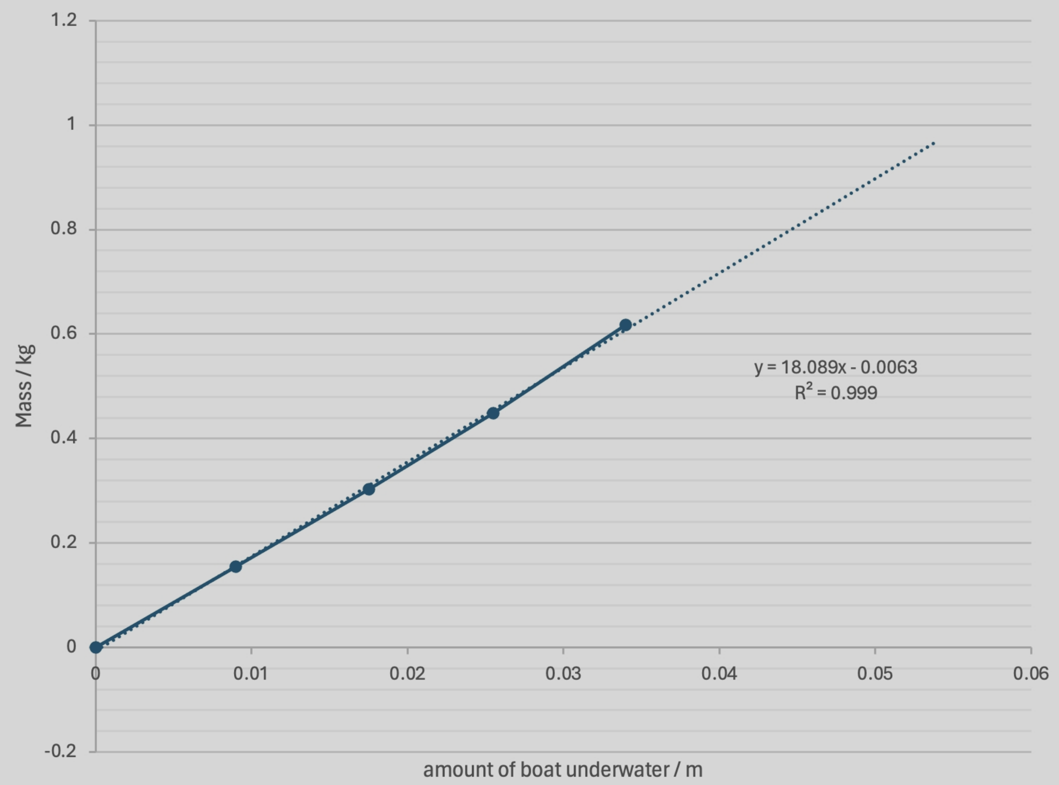
- Flotation hull volume + material
  Foam ↵
  Air (empty chambers) ↵
  ↳ Minimise material use
- Collection Object Packing
  ↳ Collection chamber dimensions
- Bridge form
  ↳ **Generative** design based on force and attachment plane constraints.

Firm Decisions

- Catamaran-like

Prototype & Dynamic Model Generation

One of the firm design decisions made initially was the use of closed cell foam as the main material in the floatation hull, the main reasoning behind being its excellent flotation capability and easy manipulation in manufacturing complex shapes. To test the material properties of the foam in relation to flotation, we generated a simple first prototype (refer to prototype page for evidence). By adding known masses to the prototype while over water and taking measurements of the amount of the ship above water (which can the be used with the known height of the hull to find the amount below the water) we generated a dynamic model which relates total ship payload and the volume of foam required in the flotation hull. This relationship aided us in optimising (minimising) the volume of flotation hull required and therefore material use, making the design more material efficient.



In order to optimise hull volume, we must generate a linear relationship between the amount of hull underwater and the force applied by the hull and other components for some constant, ψ.

$$w_{ship} \propto h$$
$$w_{ship} = \psi h$$

The graph demonstrates the empirical relation required by ignoring the small projected intercept,

$$w_{ship} = 18.089h$$

But what does ψ mean?

$$F_B = F_g$$
$$F_g = dm \cdot g$$
$$F_B = \rho_{water} g A \cdot dh$$
$$\frac{dm}{dh} = A\rho_{water}$$
$$let\ \psi = A\rho_{water}$$

So the area of the ship hull was,

$$\frac{\psi}{1000} = 1.8089 \times 10^{-2} m^2 = A$$

And the maximum weight achievable in this scenario,

$$18.089h\Big|_{h=0.05} = 0.904\ kg$$

We can now find the required volume for any desired height by adjusting the surface area based on the other constraints.

For the initial prototype,

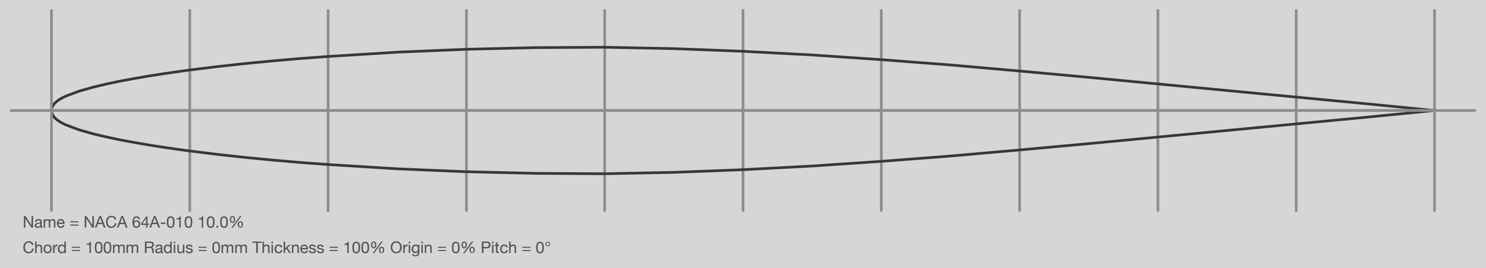
$$w_{ship} = \psi h$$
$$w_{ship} = 18.089h$$
$$let\ \psi = A\rho_{water}$$

Prototype & Dynamic Model Generation

Due to the dynamic relationship relating mass and volume, volume can be interpreted as horizontal area and depth, which enabled us to use the complex standard aerofoil NACA64A-010, while retaining the depth a variable quantity dependent on mass, which meant we did not compromise on total ship mass through our components.

The use of the NACA64A-101 heavily reduces viscous drag and enables higher achievable velocities through the minimisation of vortices forming behind the ship.

$$\text{Mass of ship} = 0.375kg + \quad Area_{NACA64A-101} = 0.018807232m^2$$



$$\text{Therefore } depth_{min} \text{ of hull} = 0.019939 + \ m$$

Manufacturing

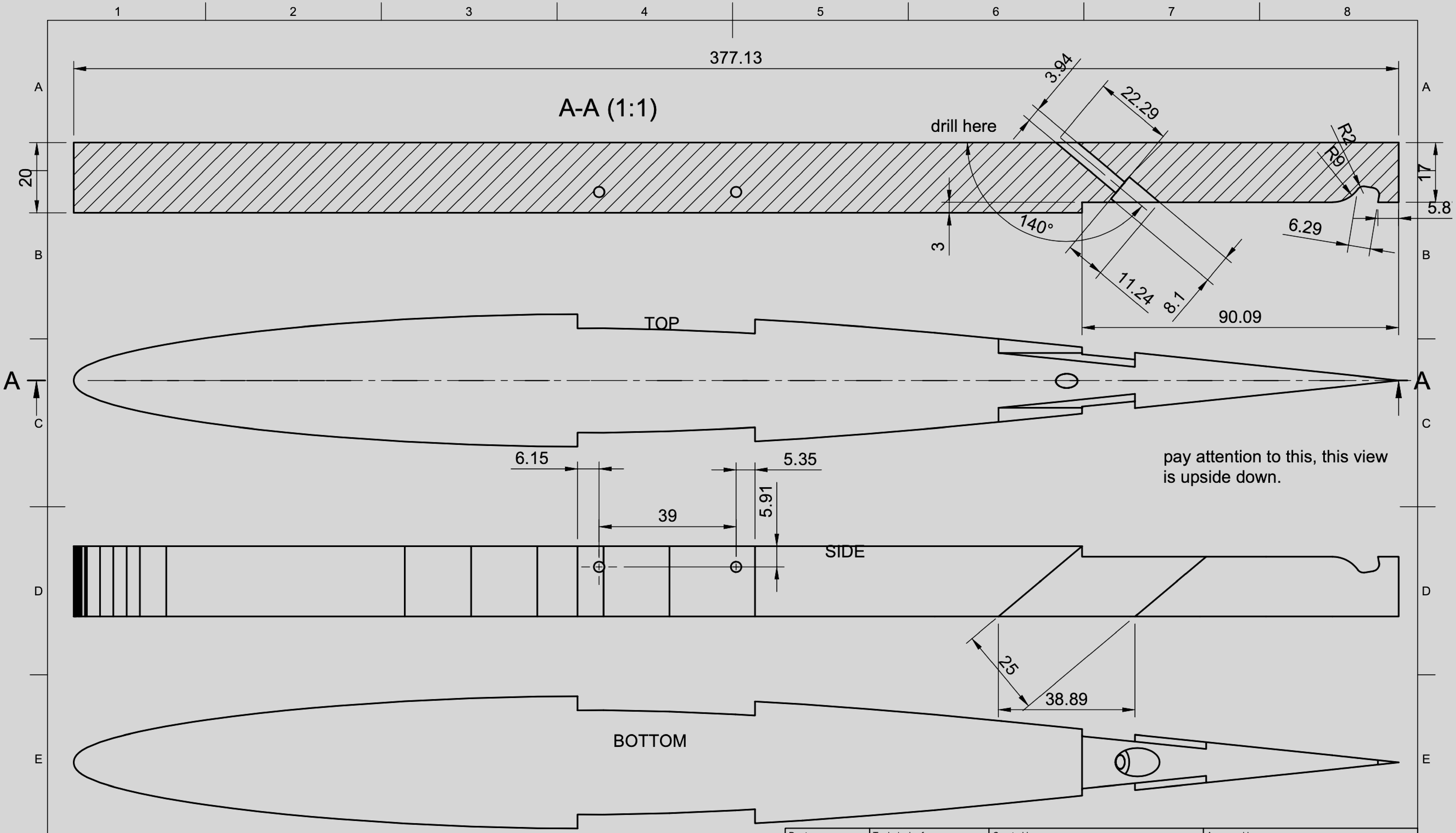
For our ship design, we went for a Catamaran ship design, due to the several advantages that it offers for our use case. catamarans have a larger distance between their hulls, which will allow us to have a large area for our gate, ensuring that we are able to collect the largest mount of balls possible. This task would be significantly less efficient with a monohull ship design. As the catamaran has 2 hulls, stability is ensured. Because of this, the ship will remain upright, which is needed for the electronics to operate effectively. The increased deck space that a catamaran offers allows us to mount all the electronics onto the deck of the ship. As we are trying to collect all balls as fast as possible, it helps that catamarans have relatively low drag forces.

The two main materials that we used were foam and PLA. Foam is a very lightweight hydrophobic and buoyant material, which is perfect for the hull because it will keep the ship afloat. As it's very moldable, it is easy to work with too and will make it easier to shape it into the aero foil shape that we are trying to achieve. PLA is very easy to print and provides high strength. This is important as it will be used to make up the core of the ship and ensure an overall rigid structure.

We decided to use additive manufacturing for our ship deck, as this allowed us to be creative with the design. This was optimal, as the optimized design for the ship that we created from fusion 360 was very hard if not impossible to manufacture by hand due to its complexity. For the foam used the hot wire foam cutter to cut out a rough outline of the hull shape before sanding it down manually with sandpaper into the desired streamlined shape.

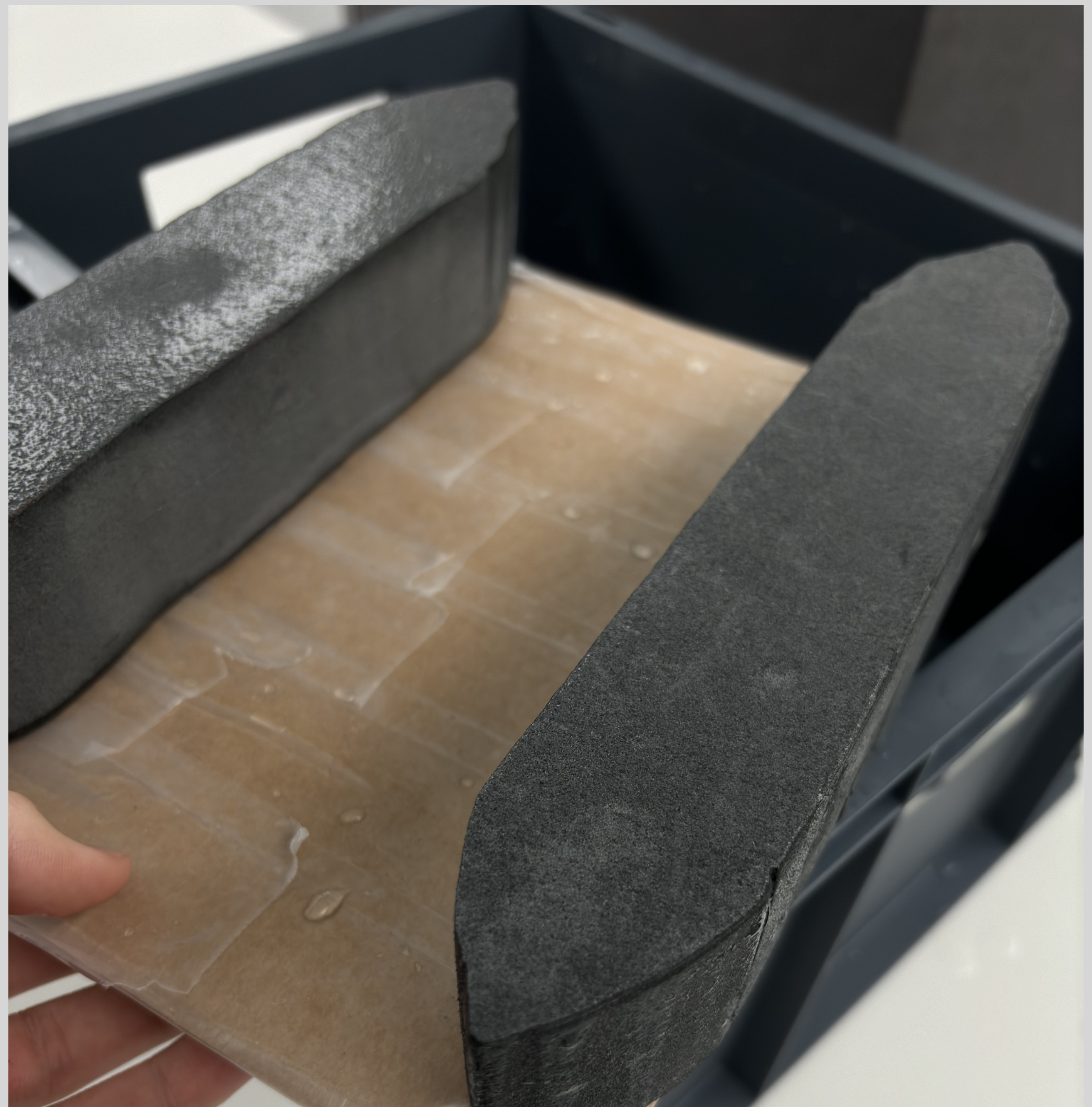
For joinery, primarily steel screws and nuts combined with the bridge and floatation hull geometries were used to strongly bond each all components.

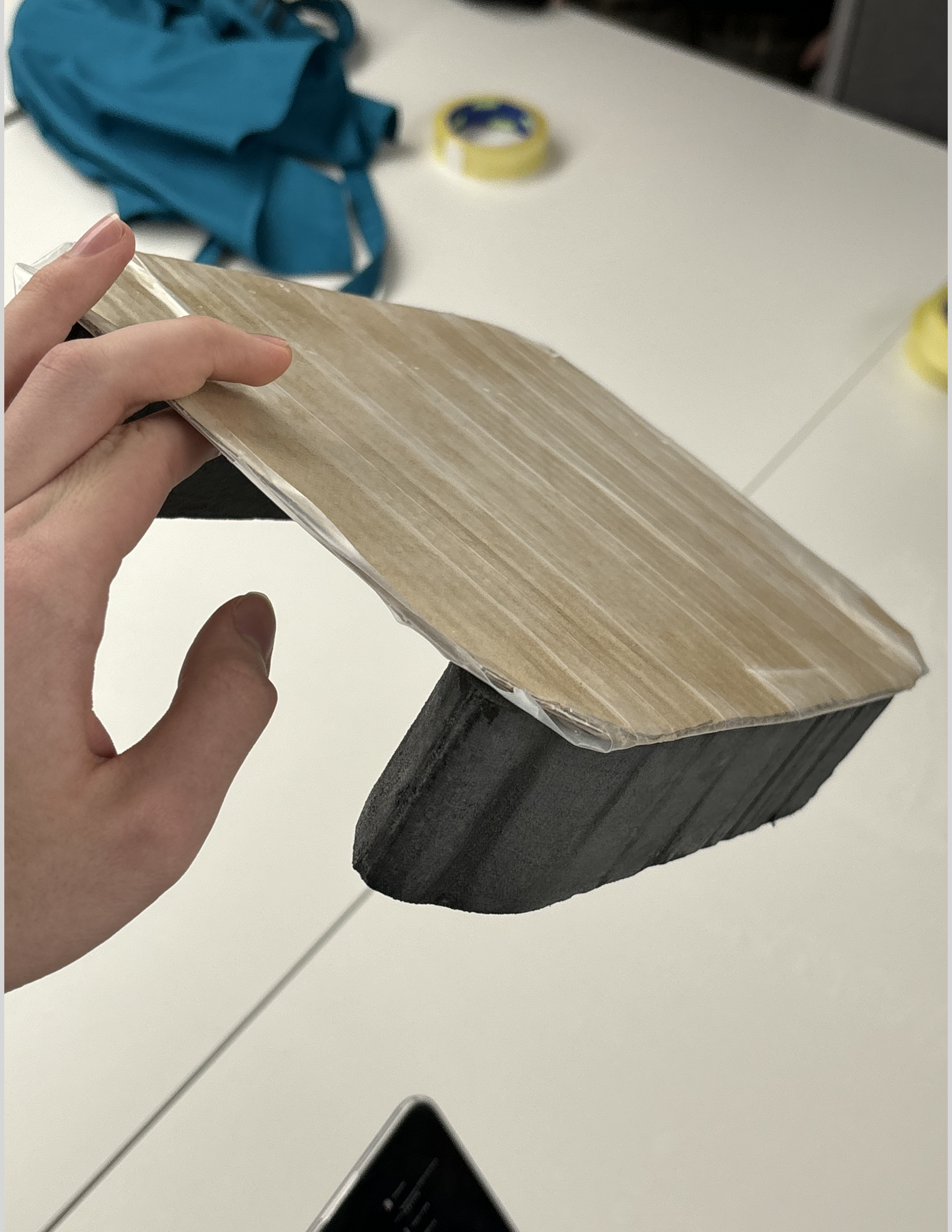
To ensure ship stability around the heel and trim, we distributed weight equally along the ship deck. Furthermore, we minimized the center of gravity as much as we could without hindering the collected balls, for increased stability. This, with the addition of having a symmetric ship design ensures good stability for our ship.



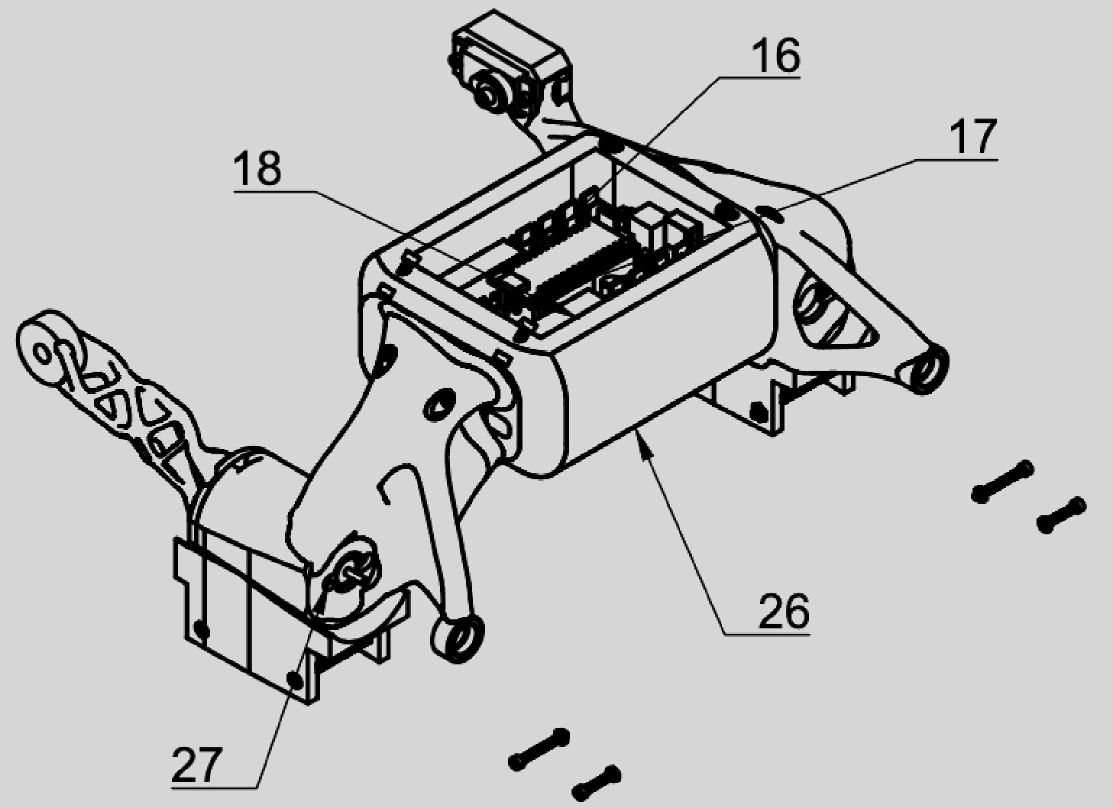
Dept.	Technical reference	Created by Aleksander Pavlov 7.03.24	Approved by
		Document type	Document status
		Title MCPgroupmaster Flotation Hull Produce 2x	DWG No.
			Rev. / Date of issue / Sheet 1/1

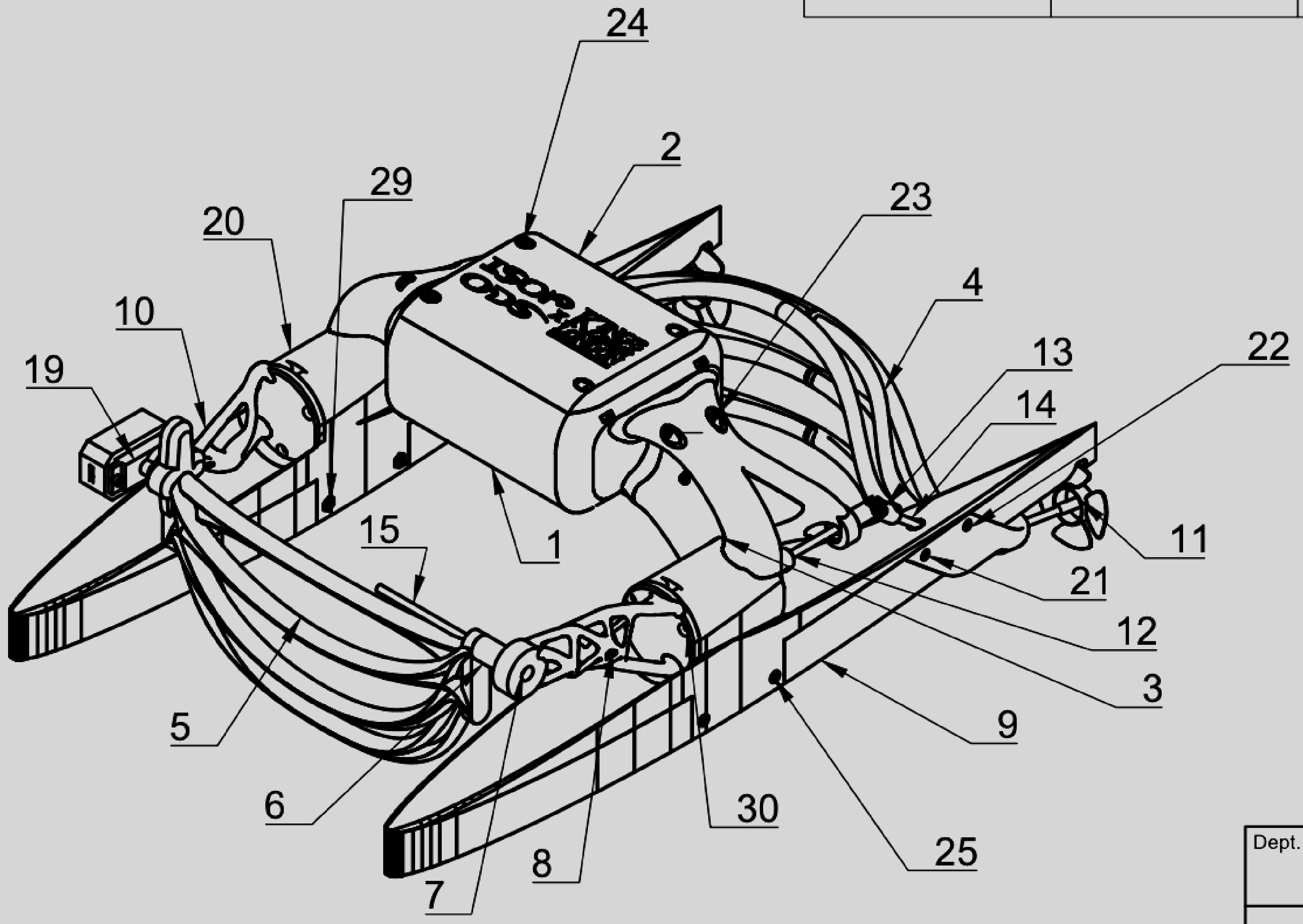
DesignBuild





DesignBuild





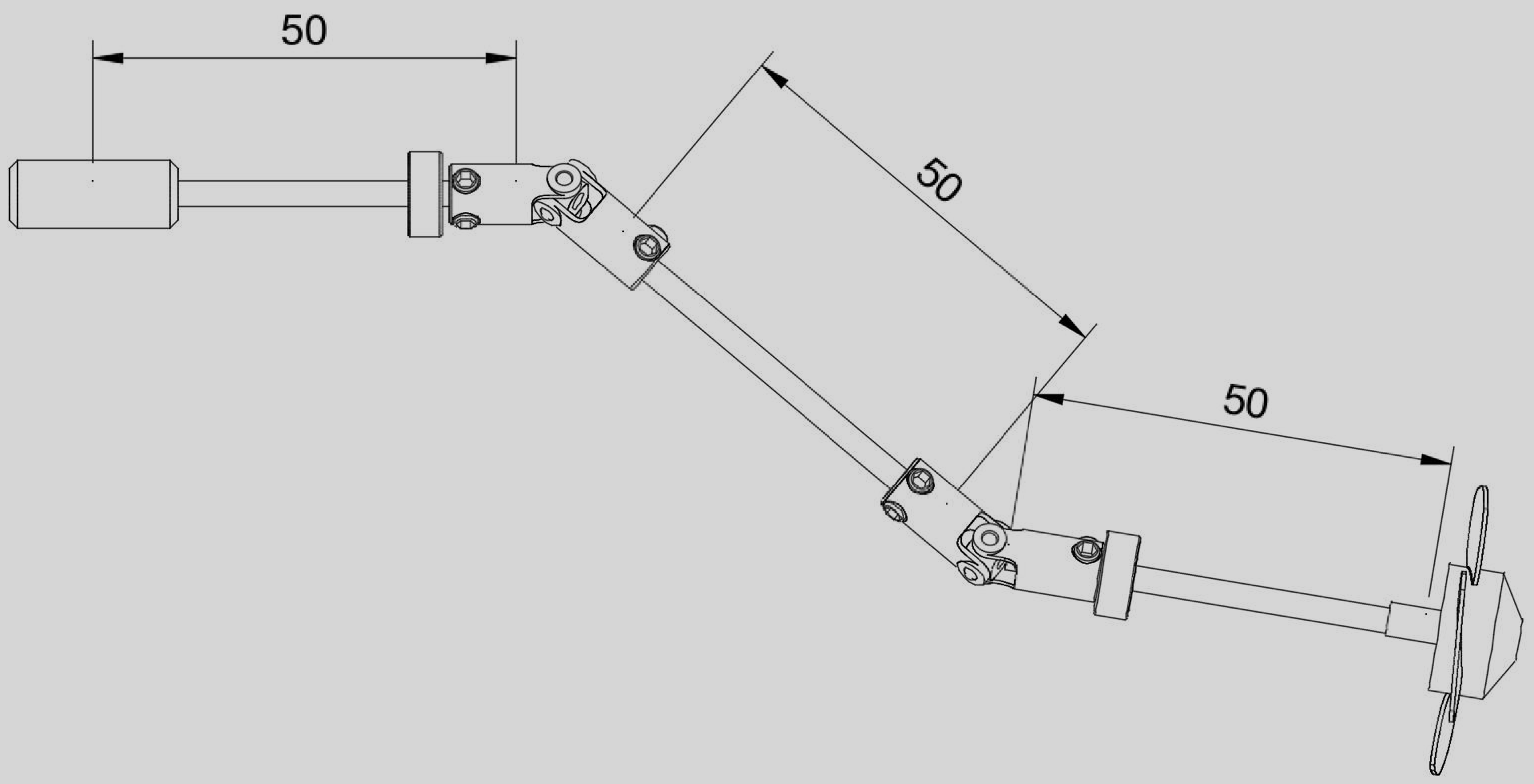
Parts List

Item	Qty	Item No.
1	1	MCU Container + Arduino Nano, Arduino Nano Motor Carrier
2	1	MCU Container Cover
3	1	Motor Holder + Bridge Structure
4	1	Rear Collector
5	1	Front Gate
6	1	Gate Spacer
7	4	3mm Bearing
8	1	Left Gate Holder
9	2	Foam Hull
10	1	Right Gate Holder
11	2	Water Propeller
12	2	Shaft Coupler 2-3mm
13	4	HUCO Universal Joint
14	6	3mm*50mm Steel Shaft
15	1	3mm*75mm Steel Shaft
16	1	Arduino Nano & Nano Motor Carrier
17	4	M2.5 Hex Spacers
18	1	Battery
19	1	SER0049 6V Servo
20	2	RS Pro 6W Brushed DC Motor
21	2	Cap Screw M2*20mm
22	2	Cap Screw M2*14mm
23	6	Cap Screw M2.5*16mm
24	4	Cap Screw M2.5*12mm
25	4	Cap Screw M2.5*35mm
26	4	Cap Screw M2.5*8mm
27	4	Cap Screw M2.5*4mm
28	4	M2 Nut
29	14	M2.5 Nut
30	6	Countersunk M2.5*8mm

Dept.	Technical reference	Created by	Approved by
		Aleksander Pavlov 24.03.24	
		Document type	Document status
		Title	DWG No.
		Group I - Complete CAD	
		BOM	Rev. / Date of issue / Sheet 1/1

Propulsion Steering

For the design of the Propulsion System, my team chose a hydrodynamic propeller and adopted a more traditional layout and transmission mode. The three drive shafts are connected by a universal joint, which allows the propeller to work properly when the motor and propeller are in different planes. Since the waterproofing of the main board and motor is very important, the main purpose of this design is to keep the engine as far away from the liquid surface as possible. In order to make the propeller waste as little kinetic energy as possible under the drive shaft connection, I took two measures, the first is to shorten the length of the drive shaft to reduce the overall weight of the drive shaft part. Secondly, by shortening the length of the drive shaft, I changed the angle of placement of the motor so that the propeller could contact the liquid surface efficiently, and the propulsive power of the hydrodynamic propeller could be utilised normally under the shortened length of the drive shaft. Thirdly, since it is difficult to ensure the angle of the propeller by the drive structure itself, my team created a fixing part on the head of the propeller by 3D printing. The structure is a fixing device that is integrated with the hull of the boat, and consists of an aperture with a bearing to fix the whole drive and propeller part. The purpose of the bearing is to minimise the friction between the drive shaft and the fixing device and to minimise the loss of kinetic energy of the propeller. In this way, the angle of the propulsion system is made more flexible by means of universal joints and cut drive shafts, and the loss of kinetic energy due to the weight and friction of the drive shafts is reduced by shortening the distance between the drive shafts and installing the bearings. The result is that the motor is able to bring power to the hull properly even when it is far away from the liquid surface. For the steering, our team used the main board to control the two motors at different speeds in order to change the direction of movement of the hull.



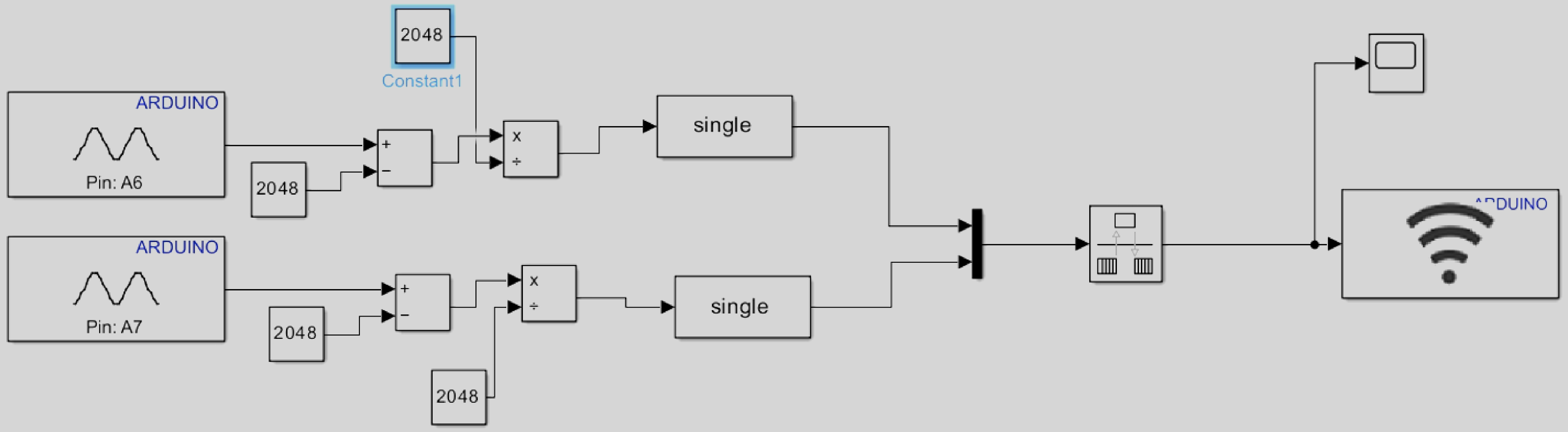
Remote Control Design

Communications software:
The role of the communications Arduino was to take the potentiometer values obtained from the joystick, convert them to a co-ordinate system and send them to the on board Arduino. This was achieved by first taking away 2048 from each value, transforming their range from (0 ,4096) to (-2048, 2048), allowing the joysticks resting state to have co-ordinates of (0,0), each value was then divided by 2048 to make the range a more manageable (-1,1).

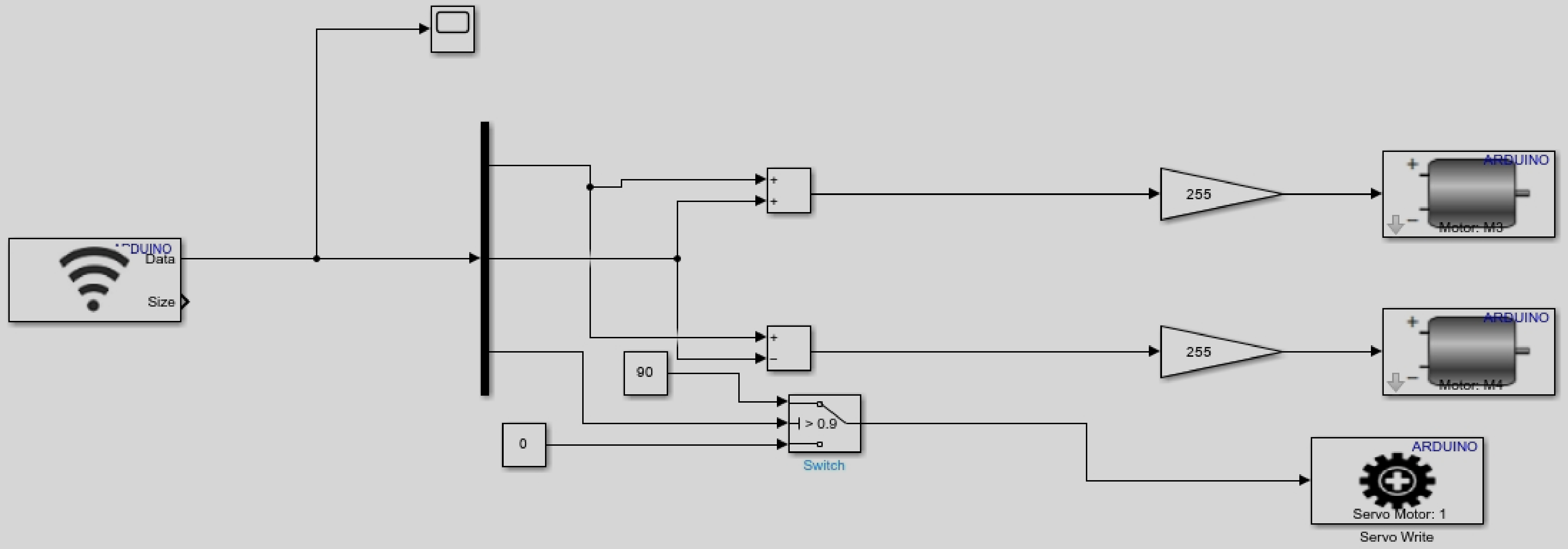
In a later version we noticed that even while the joystick was in its resting position there was a small amount of noise in the signal, to ensure this had no effect on the boat a low pass filter was implemented that would cut out all signals below an absolute value of 0.07, this was large enough to block out any noise coming from the joystick but still small enough that is wouldn't be noticeable when steering the boat.

The signals were then muxed along with an on-off signal for the servo motor and sent via a Wi-Fi UDP connection to the onboard Arduino where they were subsequently demuxed.

Communications issues:
While the initial testing of the code (sending signal between computer to test if all filters and code worked as required) was successful, we encountered an issues when uploading the code to the boards, everything compiled correctly and showed no error message however the remote controls weren't working. We tried a lot of different approaches from searching the internet to asking our professor and TA's for assistance but nothing seemed to work. Finally we decided to borrow a class mates computer that was made by a different company than ours, miraculously this seemed to work and our boards are functioning.



Onboard Control software:
The role of the onboard Arduino was to take the x and y co-ordinates provided from the communication Arduino and translate it to the thrust of each of the two motors. First the 1/0 signal is passed through a switch that turns sets the servo motor angle to either 90 or 0, closing and opening the gate, the y co-ordinate is added to each of the motors, this is pretty self-explanatory since a the further forward the joystick is pushed, the larger the forwards thrust should be and the further backwards it is pushed, the larger the backwards thrust. The x co-ordinate is then added to the left motor since a when the joystick is pushed to the right the left thrust should increase to create a clockwise torque on the boat. The x co-ordinate is then subtracted from the right motor since when the joystick is pushed to the right the right motors thrust should decrease to provide a clockwise torque. Both cases also work for creating an anti-clockwise torque when the joystick is pushed to the left.



With this set up the range of the signal to each motor is (-2,2), this is the multiplied by 150 to give a range of (-300,300), which is slightly over the (-255,255) range of the motor however the software does not seem to have a problem with this.

In a later version of the software, we addressed a problem that occurs in the initial code. Since the range is (-2,2) the max gain is 150, this means that when the joystick is fully forward the thrust is only 255 to each motor instead of the maximum 255, thereby limiting the boats max speed. To solve this we created two solutions, one involves simply making the gain 255 as the system doesn't seem to have problems with being given values outside the motors range. The other involves both changing the gain to 255 and implementing a set of filters that cut off any signals above 1or below -1, making the effective range (-255,255). At the time this report is being written neither of these solutions have been implemented as we are waiting for access to the computer that is able to upload our code.

This time both boards communicate with each other effectively and the boats movement matches the joystick and button inputs.