AFRICAN SCHOOL OF INNOVATIONS SCIENCE AND TECHNOLOGY

HYDRO SAPIENS TEAM

KAMPALA, UGANDA, AFRICA

TECHNICAL DOCUMENTATION REPORT

PROJECT MANAGEMENT

TEAM MEMBERS

TEAM COACH: **ANANTORI TUCUNGWIRE**

TEAM LEADER: **LOWENA MWIZA RUGYENDO**

ASS.TEAM LEADER: **NIINYE WILSON KING KAJWENGYE**

DOCUMENTATION AND RECORDS**:** **ANKUNDA QUEEN KAJWENGYE**

RESEARCHER: **AMIIRAH MIREMBE BAKKIDDE NANKYA**

DESIGNER: **LAUREAN RUGYENDO RUGAMBWA**

PROGRAMER: **GABRIEL JOSEPHAT KAWALYA MWEBE**

MENTORS

ALLEN NANYONJO

MAUREEN AYEBARE KARAMAGI

CAROLINE KAPERE TUSIIMIRE

Abstract

This Technical Design Report highlights the Engineering Design Process (EDP) Team Hydro Sapiens used to create the Mate Remotely Operated Vehicle (ROV) and the successful design features. This report will review the challenge course, obstacle course, and new mini-course tasks, and how they influenced the team's engineering design approach. Analysis of experimental results included in the report demonstrates how detailed testing was used to decide on the final design. Additionally, the report describes the team's reflection on the marlin journey to this point and plans for the Team Hydro Sapiens ROV design.

The design of a remotely operated vehicle (ROV) with a size of 40 cm × 35 cm × 30 cm, and a weight of 7.64 kg, is introduced herein. The main goal is to create a robot that is able to maneuver under the water to perform various tasks. The ROV moves under the 4 DC motors governed by Sabertooth motor drivers and by using pulse-wide modulation with short pulses from the Arduino controller to improve the stability of the position about the translational, ascent or descent, and rotational movements. This ROV is controlled by the barracuda control box that consists of the circuitry responsible for the smooth movement of the robot.

With the following features of this ROV, it has proved its ability to ably accomplish the mission tasks underwater as it is one of the key features for the 2024 MATE competition.

Table of Contents

WORK PLAN

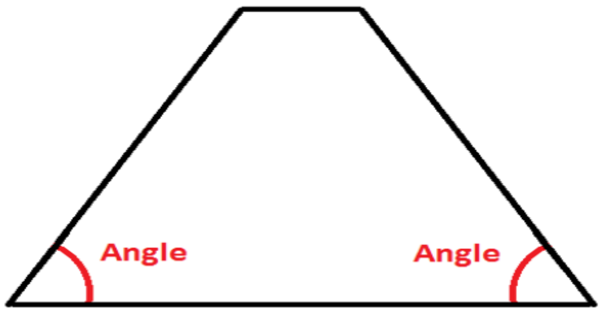
MATE ROV BUILDING WORK PLAN			
month	**date**	**activity**	**content coverrage**
	12th	**ELECTRONICS**	Multi-meter Basics
			Review, How Switches Work
	13th		Simple Circuits
			Simple Circuits Helpful Hints
			Simple Circuits Lab
	14th		Electrical Symbols
			Analog Barracuda Controller Simplified
	17th	**SOLDERING**	soldering waterproof wires
			soldeimg wires
	16th		solder and seal connectors
			learn how to solder components on the pcb board
	17th	**ROV power systems**	creating ROV power wiring
			power opptions for the ROV
	18th		power safty
	19th	**ROV analong control system**	creating the practice board
	20th		adding a switcht
			adding resistors
			adding LEDs
	21th		adding power circuit
			study how a power circuit works
	24th		building barracuda control box
			over view of the barracuda kit components
			study of barracudea pcb bard
April	25th		LEDS
			Resistors
			camera filters
	26th		fuse holders
			capacirors
			receptacle conectors
	27th		anderson powerpole PCB connectors
			head connectors
	28th		sabertooth motor controller
			study how the controllers work
			learn how ro swich driving modes
	Ist		installation of the sabertooth controllers
			wiring of the motor controllers

	2nd	**ROV tether system**	general tether information connecting tether on the control box
	3rd	**ROV SENSOR SYSTEM**	water proofing the cameras adding the cameras connecting the monitor
	4th	**ROV propulson system**	attaching the propellers to the motors craeting the tether management cross connecting the motors to the terther
	5th	**Solderingdigital components**	soldering digital componets
	8th	**computer programing**	installation of the programe testing the digital components
	9th	**AUTO CAD**	autoCAD design of the ROV
may	10th	**ROV assebly**	measuring and cutting of pvc pipes buiding of the ROV
	11th	**boyancy and ballast**	boyancy measuring flootation stability weight calculation
	12th	**COMPETION OVERVEW**	competion overvew
	15th		testing the ROV

1. Multipurpose Frame Design: The frame allows easy attachment of motors but is also hollow to reduce drag and overall ROV size to provide maximum thrust-to-mass ratio for peak ROV speed.
2. Adjustable Buoyancy; Foam floating tubes, and the vertically oriented motors are used to adjust buoyancy between positive, negative, or neutral. The buoyancy from tubes and other frame structure volumes contributes to the buoyancy due to viscosity. The vertically oriented motors propel the water up or down, this enables quick adjustments based on the complex mission tasks the ROV has to pursue.
3. Gripper: The ROV gripper is used to lock floating tools place and grab material to be handled, The Innovative Part is the hydraulic gripping mechanism, the innovative design enables tight gripping and makes it more maneuverable throughout the mission tasks course.

DESIGN APPROACH

The first step of the ROV design is to survey tasks and research what improvements are needed to complete the ROV most efficiently. We looked at the most continent design that could be more stable in the water, there we came up with the trapezium shape that could enable us to align motors vertically to a achieve stability



We chose this design to improve stability because we intended to increase more material at the bottom of the ROV and less on top. To achieve this, we had to choose the trapezium to ensure more weight at the bottom of the ROV which shall be compensated by the buoyant materials to ensure a neutral position on water. After looking at the principle the submarine uses to be stable in water. The answer lies in the weight-buoyancy relation maintained in submarines. When the weight of the submarine is more than the buoyancy, it sinks until any corrective action is taken to reduce the weight or increase the buoyancy i.e. Negatively Buoyant. Here we achieved this by adding less and more buoyant materials at the top of the ROV.

Framework design

The framework was designed from PVC material, PVC pipe is durable and water-resistant, making it the perfect material for applications where the pipe will need to be submerged. Looking at our design we procured PVC pipe and did measuring and cutting.

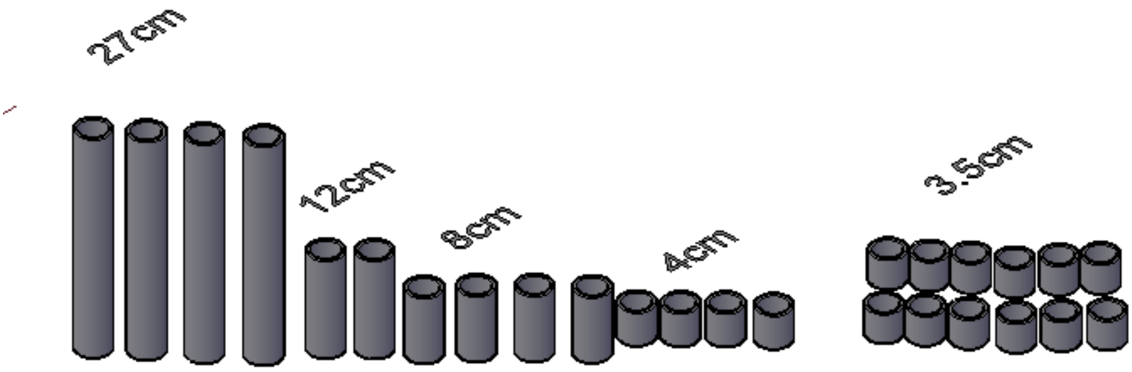


Figure 1cut pvc pipes

The measured 4 pieces 27cm, 2 pieces 12cm, 4 pieces 8cm, 4pieces 4cm, 12 pieces 2.5cm,

We then obtained the 5 right-angled PVC joints, that helped to join the straight PVC pipes to come up with a planned framework, these joints we used on the end joints of the robot.

We also obtained the 20 T section pieces, these helped us to join straight PVC pipes to come up with the planned design shape, we also used these joints at some end joints to work as water outlets from the robot we then joined the pieces together to come up with the required fitting

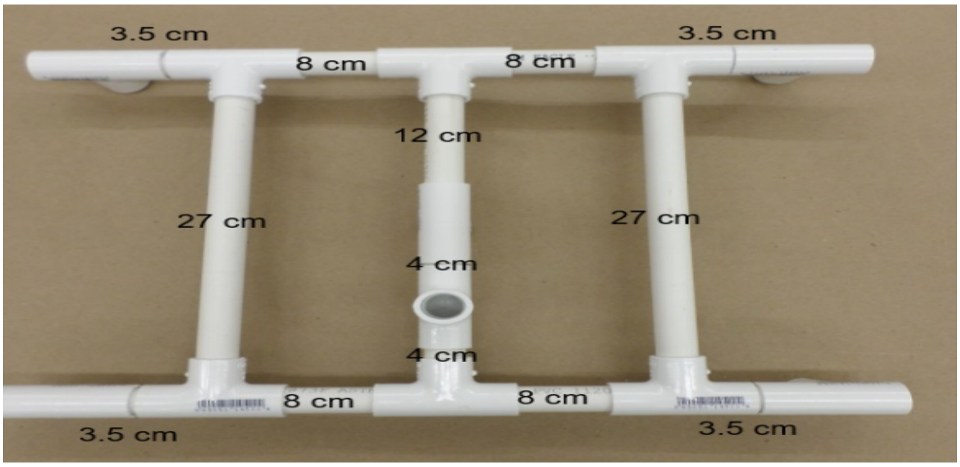


Figure 2 pieces joined together

We then came up with the design for one side of the robot and made two of these to form a full complete framework.

we formed the final framework design of the ROV by joining the two sides together, to ensure stability and to make sure all parts fit together without loosening, we fastened the joints with self-taping screws that could help to ensure each joint is firmly held to avoid a breakdown during the operations of the ROV

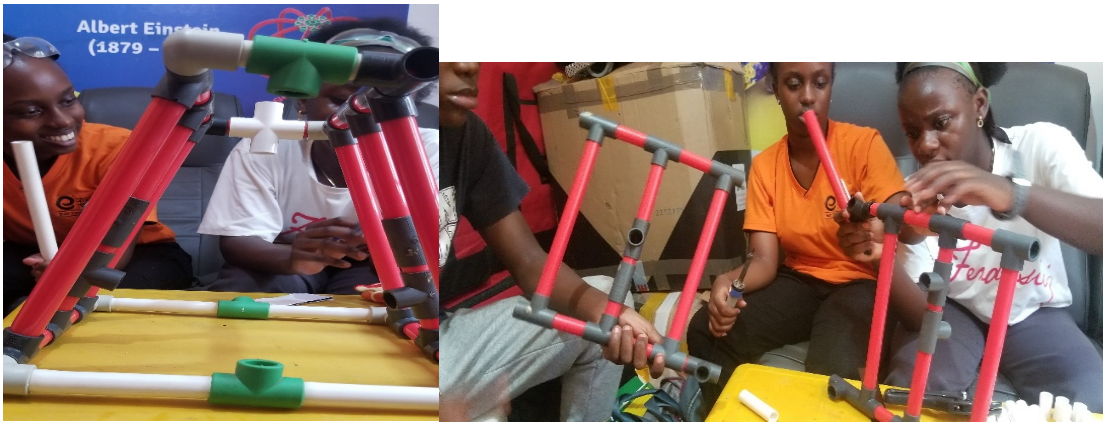


Figure 3 building

On one of the top-width sides of the robot we used the cross joint to allow easy connection of the tether communication cables that will be transmitting signals to the ROV motors, this would at the same time enable us to waterproof the wires at that joint.

- **Motor orientation**

After construction and successful joining of the pieces we then had to decide on the best motor orientation mechanism that would favour us to achieve stability and also help to propel the robot successively under the water

Basing on the electronic circuit that we had designed in the barracuda box; it could accommodate only four motors and therefore we had to determine the best mounting position of these four motors without affecting the robot’s stability and balance. Ignoring the additional parts, we considered robot symmetry to ensure the motors are put in a straight line that divides the robot into two equal parts that divide the weight respectively, this helped to keep the robot balance intact after the addition of the motors.

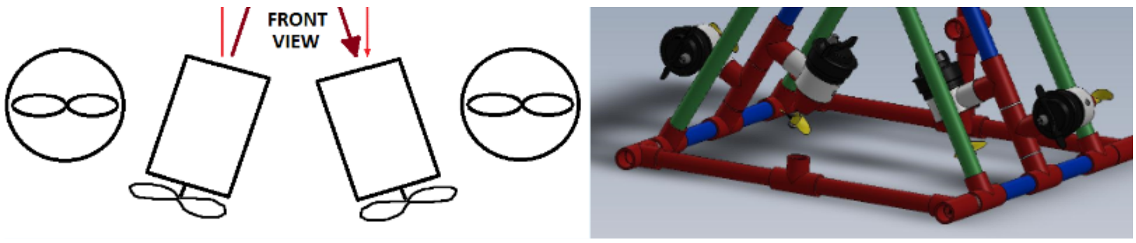


Figure 4 motor orientation

With this motor configuration when the two vertical motors rotate in different directions, the x-axis motion is achieved provided the robot is steadily stable this is because the two vertical forces councils resulting in a horizontal component that enables the robot to move in the x-axis direction. This works respectively for motion in the y-axis when directions are reversed.

When all the vertically mounted motors rotate in the same direction, they will move the robot down the water or up the water depending on the direction of the propulsion. When the ROV is in the neutral position, propulsion of the water under the robot will create an upthrust force that will cause the robot to move upwards, this causes the robot to be more buoyant due to the fact that the weight of the robot has been opposed, yet we know the reduction of the wait increases buoyance of the robot.

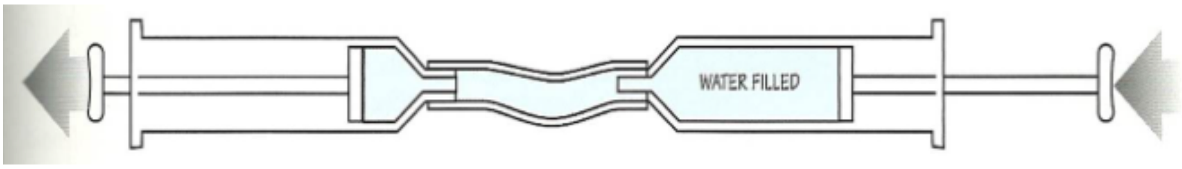
The two other motors are mounted in the horizontal orientation, this position enables the ROV to move forward or back depending on the direction of the water propulsion when the water is propelled in a backward direction by both motors, the robot will equally propel forward, as a reaction due to the action of the water flow.

In addition to moving forward and backward, this motor configuration enables the robot to turn around during the control. When the two motors propel water in different directions, the robot will rotate in one direction, for instance, if they take an anticlockwise direction then, the ROV will take the opposite direction and vice versa.

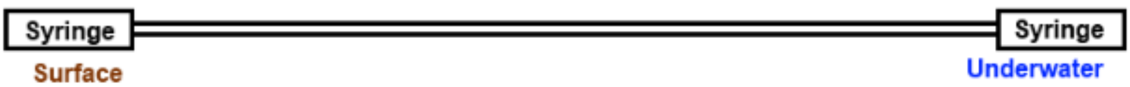
- **The hydraulic manipulator**

We used the hydraulic system to create a gripping mechanism, following the principle of Pressure applied anywhere to a body fluid causes a force to be transmitted equally in all directions, with the force acting at right angles to any surface in contact with the fluid pressure, identify the amount of force required to accomplish the intended task in your system. This could be lifting or moving an object, applying pressure, or performing any other application-specific requirement.

We chose a suitable hydraulic cylinder actuator that can generate the necessary force, considering factors like piston diameter (or area), stroke length, and load conditions.



We determined the effective surface area on which the force will be exerted. For a cylinder, this was calculated using the formula: Area = π * (Diameter/2)^2, where Diameter is the internal diameter of the cylinder. We applied Pascal's law to calculate the hydraulic pressure needed. Substitute the force and area values determined in steps 1 and 3 into the formula: Pressure = Force / Area.



Since we used the equal syringes in transmitting the force, from F1/A1=F2/A2 an equal force is applied to the gripping mechanism.

For the gripping mechanism, it was extracted from the fast class of levers which enabled an efficient gripping mechanism.

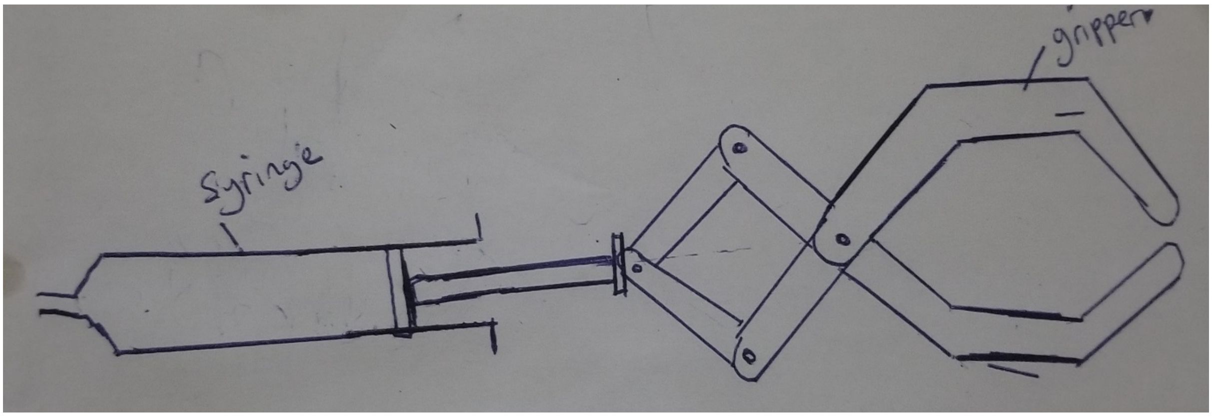


Figure 5gripper design

Before coming up with the above mechanism, we tried several designs that proved not to be convenient

After getting this we 3d printed the necessary parts and then joined them together to come up with the above design

Figure 6gripper

With this gripper the robot accomplishes the mission tasks without any strain or stress of any part of the ROV, the mechanism being lighter, it does not affect the balance of the robot, this arm if fixed at the bottom part of the robot ensures the ROV is able to handle material that could u at the bottom floor of the pool.

Buoyancy

The buoyant force is the upward force exerted on an object wholly or partly immersed in a fluid. This upward force is also called Upthrust. Due to the buoyant force, a body submerged partially or fully in a fluid appears to lose its weight, i.e. appears to be lighter.

Everybody on the ROV has mass and thus has weight, this causes the robot to think in the water, but at the same time, the body has volume which will displace water leading to upthrust force and increasing floatation. From Archimedes's principle, the buoyant force acting on the body is equal to the amount of fluid displaced, on this ROV, we ensured buoyancy by adding the floating form tube material because they are light and have a larger volume, this enabled us to balance the total weight of the ROV with the volume, making it a neutrals buoyant

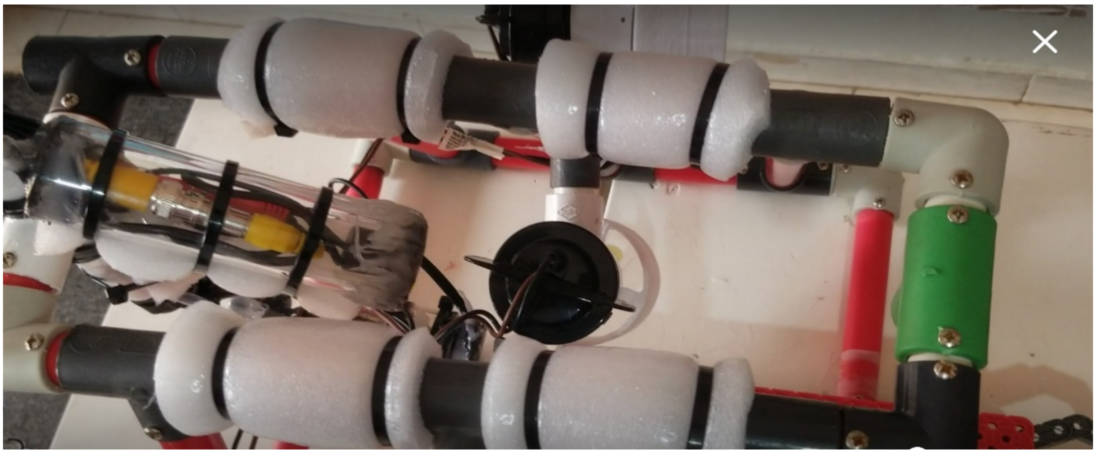


Figure 7 floating elements

All liquids and gases in the presence of gravity exert an upward force known as the buoyant force on any object immersed in them.

Buoyancy results from the differences in pressure acting on opposite sides of an object immersed in a static fluid.

We considered following factors affect buoyant force:

- the density of the fluid
- the volume of the fluid displaced
- the local acceleration due to gravity

An object whose density is greater than that of the fluid in which it is submerged tends to sink. If the object is either less dense than the liquid or is shaped appropriately (as in a boat), the force can keep the object afloat. In terms of relative density, if the relative density is less than one, it floats in water and substances with a relative density greater than one sink in water.

When our ROV is immersed in water , we observe that it experiences a force from the downward direction opposite to the gravitational pull, which is responsible for the decrease in its weight. This upward force exerted by the fluid opposes the weight of ROV immersed in a fluid. As we know, the pressure in a fluid column increases with depth. Thus, the pressure at the bottom of an object submerged in the fluid is greater than that at the top. The difference in this pressure results in a net upward force on the object,

Generally, our robot is a neutral buoyancy, we achieve the negative buoyancy by the vertical motors propulsion of water leading to opposite reaction force.

- **Waterproofing the cameras**

The camaras we procured were not waterproofed, therefore there was need to waterproof them to avoid being damaged by water. Here we placed the cameras in the transparent cylinder that was provided with in the Mate kit and then seals the camera inside that cylinder with epoxy. The purpose of epoxy is to seal the cameras lens to avoid water entering the camera and affect its visibility

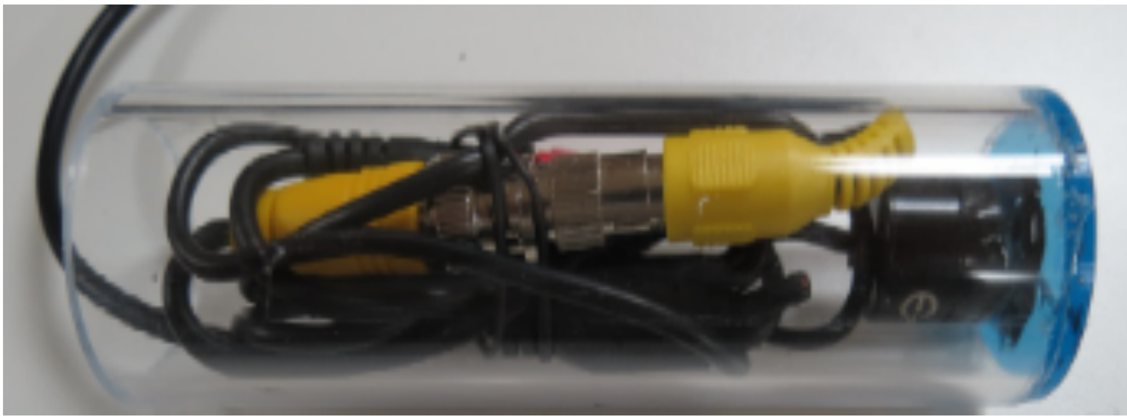
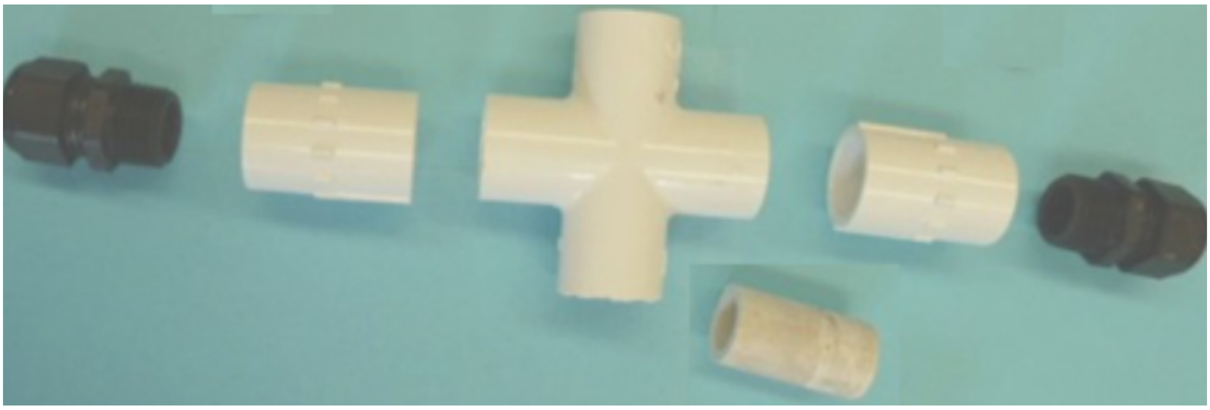


Figure 8water proofing

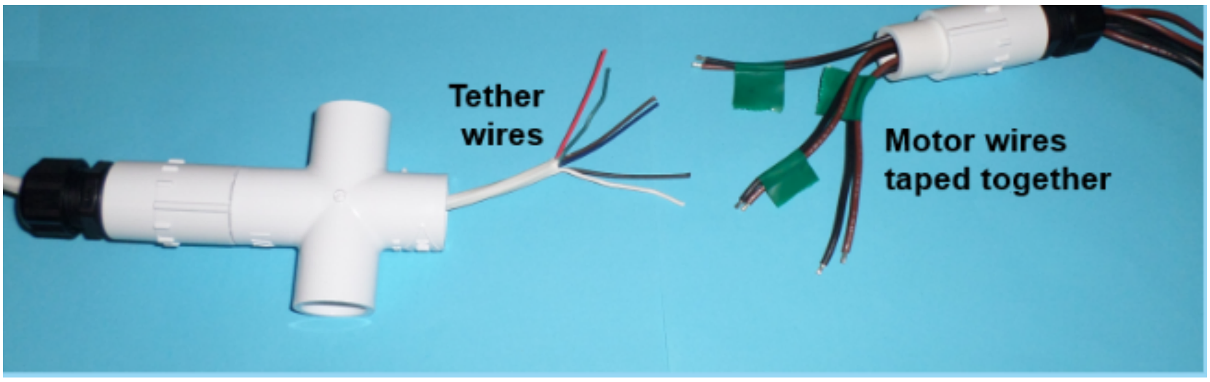
The camara and the cables were placed inside the cylinder sealed with epoxy, after drying ot wa perfectly protected from the water leakages

- ***Connection of the tether cable on ROV***

We attached the tether management cross on one side of the ROV frame for easy connection of the tether cable with the strain relief, the train relief was attached to protect the cable from breaking off once the force is applied on it, the strain relief has a rubber tube inside it that helps to hold the wire to avoid capillarity of the water up into the cable.



More so the wires inside the cross PVC joint are connected together from and passed through the strain relief in both ends, they are then soldered together, insulated and water proofed to eliminate short circuit



This eliminates the loose connection that could affect the electric flow through the cables connecting to the motors. We then water proofed the tether cable by using hot glue to water entry inside the cable that would result into capillarity water to the control box

- **Waterproofing wires**

We carried out water proofing of wires by use of the teat think tubes, these enable the cable to be held so tight at the soldered joint to ensure no water entry into the cable, once the heat sink tube is put around the wires, we use the hot air blower to contract the tube on to the joint.

Building of the barracuda control box

we obtained the barracuda control box from Sea Mate, this box contained several electronic components that helped us assemble the barracuda control box, before we started assembling the barracuda box, we started by studying and understanding simple electronics with the guidance of our coach, we practised several electronic activities that involved

- malt meter basics
- how switches work
- we looked at simple circuits
- electronic symbols
- basics of Arduino programming
- the h bridge control of motors
- pulse width modulation
- how potential meters work
- how to do soldering of the the wires

using the knowledge we have acquired from the above lessons, we then started on the assembly of the barracuda box, here we started with identifying the components and the symbols that were printed on the PCB board, then we started soldering the components until we came up with the complete circuit.

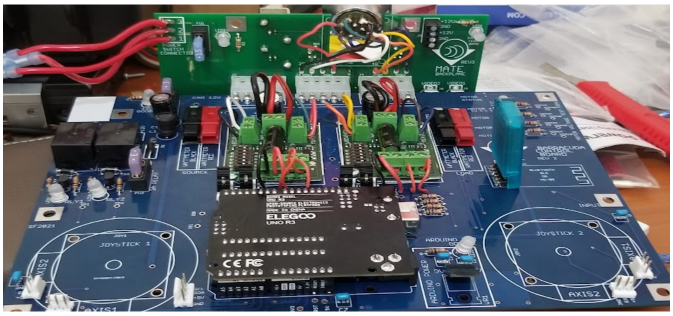


Figure 9 internal parts in barracuda

We installed the sabretooth motor drivers the Arduino controller and the joy sticks following printed PBC board, we then plagued in the appropriate fuses ensuring each fuse is plagued in the right position.

we connected the wires from the motors to the tether following the appropriate colour coding we then tested the continuity using the multmeter

Black wire	Connector pin 11
White wire	Connector pin 8
Green wire	Connector pin 12
Red wire	Connector pin 10
Orange wire	Connector pin 3
Yellow wire	Connector pin 1
Brown wire	Connector pin 5
Blue wire	Connector pin 2

We then carried out testing of the power circuit, tested the current and the voltage flow which was the recommended on,

We then mounted the watt meter, this enables the us to know and determine the power used by the ROV, carry out voltage regulation in the circuit system.

We then powered the circuit, every thing worked appropriately as we expected,

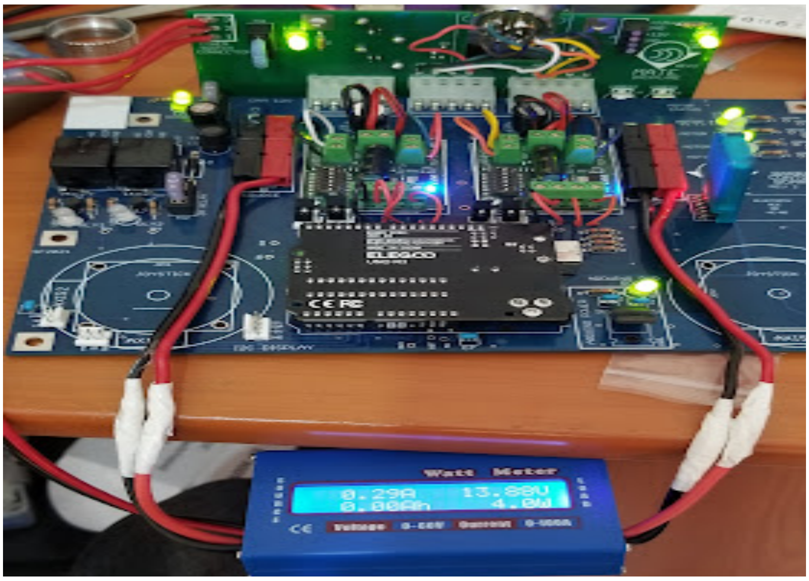


Figure 10 powered board

After testing and confirming that every thing well, we then mounted the whole setup into the barracuda box, we connected the screen video pins and also the screen and camera power pins.

We then tested the cameras and the screen to ensure every thing is working properly

Finally, we had a complete barracuda box that is ready to control the robot, we then uploaded the computer programme, to run and test the joy sticks and the motor response, we then switched the Saber Tooth motor driver to the right drive mode to ensure there is a collect response of the motors.

Testing; Having confirmed that every thing is working well, we then connected the tether cable from the robot to the robot and tested the ROV. We took the ROV at the pool for further testing.

ROV design costing

Organisation	**African School Of Innivation Sceince And Technology**				
Team name	**Hydro Sapiens**				
Sponser	**ASIST**				
Fund Date	**Type**	**Category**	**Expence**	**use**	**Amount**
10/04/2024	purchased	hardware	PVC pipes & joints	for building Rov frame	$ 55
25/03/2024	purchased	electronics	barracuda control box kit	designing control box	$ 605
25/03/2024	purchased	hardware	Barracuda motors and propeller kit	propulsion system	$ 180
25/03/2024	purchased	electronics	7.6 m teher kit	wiring	$ 55
10/04/2024	purchased	tools	tools	used during designing	$ 150
25/03/2024	purchased	electronics	soldering wire	uded for soldering	$ 5
25/03/2024	paied	transport	shipping & transportation	transport	$ 150
			TOTAL		**$ 1200**

Final design

User manual

In order to control this ROV, its is important to understand the following operation procedure

1. Once you have this ROV in place, fast check if all parts of the ROV are firmly attacked and on loose connection of any cable on the robot
2. Connect the tether cable from the robot to the barracuda control box and fasten the stress relief nut to ensure the tether wire is properly connected.
3. Connect the camera slot on to the barracuda box, and ensure it's properly connected.
4. Connect the cameral power pins to the camera power supply
5. Connect the power cable from the 12-volt power supply, the polarity of the wires is important
6. Gently place the ROV into the pool or any other non-moving water body you wish to control the ROV from
7. Switch on the 12 v power supply
8. Switch on the power switch that is located at the back side of the barracuda control box, the signal led should now be on in green
9. Stand in front of the control box facing the screen
10. To move forward, slowly tilt the left side joystick upwards, (away from your position)
11. To move backward, slowly tilt the left joystick downwards, (towards ur position)
12. To rotate the right side, slowly tilt the left joystick on the right side position
13. To rotate the left side, slowly tilt the left joystick on the left side position.
14. To move the ROV down into the pool, tilt the right joystick downwards (towards your position)
15. To move the ROV upwards from the pool, tilt the right joystick upwards (away from your position your position)