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10 & 12 CHAI CHEE LANE, SINGAPORE

ORCA ROBOTICS

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1. INTRODUCTION

1.1 ABSTRACT

ORCA Robotics presents RED V, a first-generation ROV capable of repairing damaged cables and buoyancy modules, removing fishing nets and farming seagrass, and having the ability to differentiate between morts and live fish and measure the size of fish.

The ROV's cuboidal frame is equipped with 2 Cameras, six thrusters and a manipulator. Our simple yet highly optimised modular design allows for successful navigation and task completion. Its chassis is built from aluminium T-slots, making the ROV versatile and lightweight. Our onboard electronics are housed in a Bopla Bocube and consist of a Pixhawk, Raspberry Pi, Buck-converter and 6 ESCs programmed with Python. It is widely used with multiple well-developed libraries for GUI and vision recognition. Other features include a six thruster configuration that grants the ROV six degrees of freedom, making driving intuitive and precise.

As a first-year team, we faced many challenges. We did not receive much support from our school and lacked an experienced technical mentor. We also faced difficulties acquiring a suitable swimming pool to test our ROV. We also faced challenges in the organisation. Furthermore, never having managed such big scale projects, despite our efforts in extensively planning, we lacked in executing our project management plans.

ORCA strongly believes in providing a modular, inexpensive, and robust ROV that has the capabilities to adapt to our client's every need fast.

1.2 COMPANY PROFILE

ORCA Robotics (Figure 1) is a company of 15 employees founded in August 2021. We are led by the CEO, CFO and the heads of our four departments - Design, Electronics, Mechanical and Programming. The directors and heads work together to assign tasks to the rest of the employees. For example, when delegating tasks for the design, we created sub-teams for the frame, manipulator, electronics and buoyancy sub-systems, with team leaders for each sub-team being the members with the most CAD experience. This ensured that our directors did not get overwhelmed and allowed for a clear flow of information. This structure resulted in an efficient work allocation as the tasks are balanced between our employees.

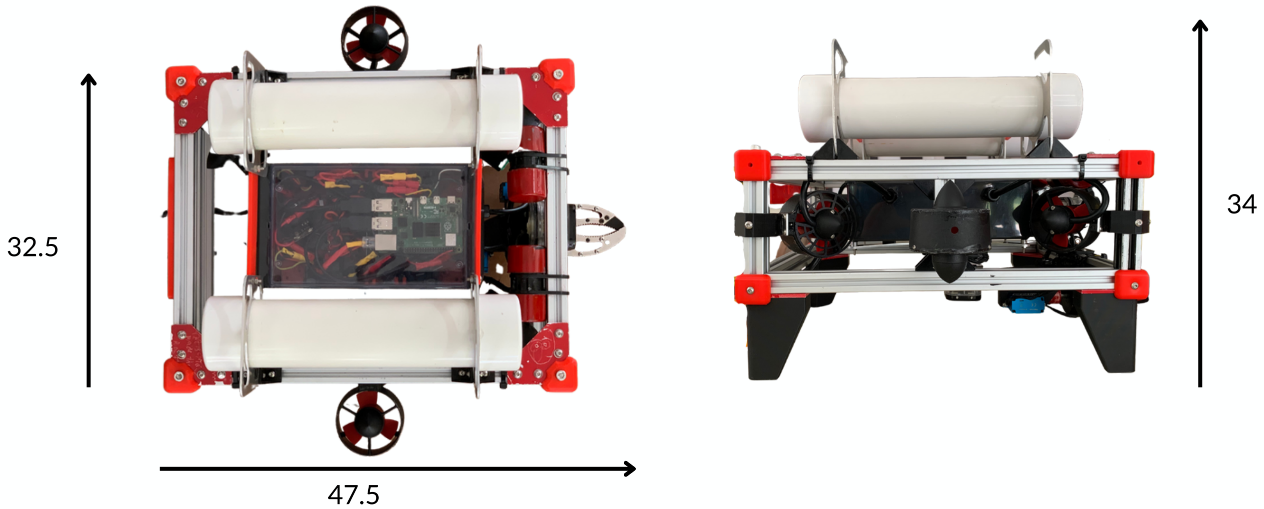
Figure 1: Our Team

2. DESIGN RATIONALE

2.1 ENGINEERING DESIGN RATIONALE

2.1.1 ROBOT SPECIFICATIONS

We take pride in the creation of a robust, affordable and effective ROV (Figure 2). Our philosophy of customising each element of the robot to better suit our needs has allowed us to create a robust design. (Refer to Figure 2 for dimensions)



5.2kg without Tether, 6.2kg with Tether

Figure 2: Robot with its dimensions displayed in cm

2.1.2 FRAME

Figure 3: T-Slot aluminium frame

Our initial goal was to maintain superior thrust vector control for 6 degrees of freedom while utilising the least number of thrusters possible. However, we soon found our exploration of platonic solids (e.g. octagons, dodecahedrons and icosahedrons) was a dead end due to higher construction and software complexity. After extensive discussions and multiple iterations, we eventually discovered that a cuboid (Figure 3) was the simplest, most compact and space-efficient design. Another such epiphanic moment was to use aluminium (lightweight yet strong enough) T-slot linear rails (20x20mm) to create a sturdy and light frame after being inspired by our 3D-Printer. This trivial decision created a modular platform where we could swap out components, adjust their positions and optimise our parts for the various tasks on the fly.

The use of T-slot rails paid off when we purchased robust, cost-effective and readily available 90-degree steel plates and assembled the robot frame in under 30 minutes. Furthermore, we were able to attach 3D printed legs (To reduce stress on the manipulator and the bottom camera) and bumpers and adjusted our buoyancy very late into the season with ease, thanks to this initial choice.

2.2 VEHICLE SYSTEMS

2.2.1 MANIPULATOR

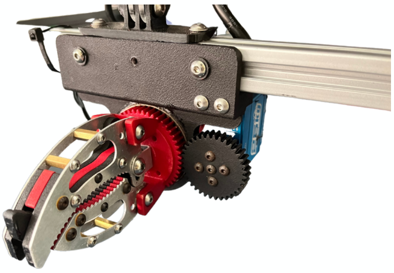


Figure 4.1: Manipulator claw close and vertical

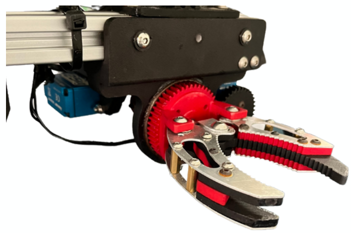


Figure 4.2: Manipulator claw open and horizontal

Our company realised that a reliable manipulator was vital, being the only component that interacted with the props. However, due to limited time and the inability to prototype a claw design, our team decided to borrow inspiration from the already tried and tested Blue robotics subsea gripper. The front claw was adapted to include 3D printed parts and Aluminium CNC plates held together by screws and threaded (Figure 4) inserts for increased robustness and ease of repair. However, here is where the similarities with the Blue robotics subsea gripper end.

We considered implementing a lead screw design but opted to use a slider-crank mechanism powered by a cheap waterproof servo (LW-25MG) to open and close the claw due to its effortless waterproofing and assembly. Additionally, our company added a second servo (LW-25MG) and a gear system to rotate the gripper. Different tasks require different claw angles; for example, the inter-ray cable tasks require a vertically oriented claw, while seagrass pruning requires a horizontally oriented claw for maximum efficiency. Furthermore, We lined the edges of the manipulator with rubber tape to significantly increase its grip.

The LW-25MG provides an incredibly high torque of 25kg while being waterproof out of the box. These features make the servo perfect for swiftly opening, closing and rotating our claws; additionally, the high output force ensures we never lose grip of our props. Overall, We built our claw ($143.68) almost four times cheaper!, with more functionality than the Newton Subsea Gripper ($590).

2.2.2 BUOYANCY

We opted to use PVC (63mm OD) pipes for buoyancy (Figure 5) since they are easier to mount on the robot than foam appendages and pool noodles. Moreover, the buoyancy of PVC does not vary with changes in depth. The buoyant force acting on the tubes is affected by the density of water, volume of air in the PVC pipes and gravity. The length of the PVC pipe is 22cm, as found from the calculations below.

Gravitational Force (-) = Mass of the ROV * Acceleration due to gravity.
= 5.2 * 9.81 = 51.012 N

Buoyant Force (+) = Density of Water * Volume of Air in PVC Pipes * Acceleration due to gravity.
= 1000 * (π * (30*10-3)2 * 0.92) * 9.81
= 8.12 π = 25.5 N

However, with real-life testing, the length of the PVC pipe looks very different as the volume of water displaced by the rest of the robot needs to be considered. We used our theoretically calculated lengths of PVC pipes and attached weights to the robot until it was neutrally buoyant. After this, we subtracted the length of PVC that amounts to the robot's weight seen in the following calculations. The new PVC length is 22 cm.

Figure 5: Buoyancy Module

Length Of PVC to Remove = (Mass of Weights Added to the ROV)/(Density of Water *Area of PVC)

= (1.94)/(1000 * π * (30*10-3)2) = 70cm

The purpose of keeping the ROV neutrally buoyant is to increase the drivability of the robot. When the net force acting on the ROV is zero, its position will only change if an external force (as provided by the thrusters) acts on it. Precise manoeuvres become more manageable as the driver is not fighting backlash anymore. Additionally, we added smaller PVC (23mm OD) pipes to the front of the robot to offset the extra weight of the manipulator to prevent the robot from tilting forward.

We used custom CNC plates and locally purchased angular gussets for mounting the PVC using T-nuts directly onto the adjustable frame, due to which minor changes to the length of the pipes are painless to account for. Furthermore, the buoyancy tubes can effortlessly be pivoted out of the frame allowing room for repairs and changes to the electronics.

3.3.4 PROPULSION

RED V uses 6 T-60 thrusters, with four thrusters placed at 45 degrees in a cuboidal frame and two placed on opposite sides parallel to the ROV. Such an X-shaped configuration provides the most degrees of freedom at the lowest cost (the least number of thrusters). Furthermore, it equally shares the load between four thrusters regardless of the axis of motion.

Figure 6: Thruster on the frame without shrouds

We chose the T-60 ($54.74) Thrusters over more conventional Blue robotics T200 ($200) thrusters mainly because they were almost four times cheaper. We also found out that the T-60 thrusters were more compact and could produce 1.65kg of thrust, which was sufficient for lifting the max 1kg mass required by the challenge.

Each motor lead was passed through the appropriate Wetlink and placed into the electronics box using a C nut. Furthermore, each thruster was mounted on a 3D Print (inexpensive and quick to manufacture) that could easily be slid onto the side T-slots (Figure 6). These features allow spare modules to be created and swapped out for broken ones in minutes!

As seen in the Figure 7 RED V utilises a vectored system to allow the ROV to move forward, backward, translate left and right, and turn. This improves user usability and makes the ROV precise in its motion. Also, all propellers are fitted with custom-designed IP20 propellers.

The most significant drawback of this system is limited pitch control; however, our software design system was able to use its gyroscope for fine-tuned control to make sure our ROV is always balanced along with our buoyancy system.

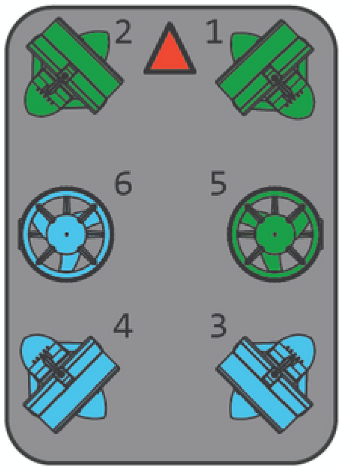


Figure 7: Thruster Arrangement taken from blue robotics ArduSub

3. ELECTRONICS

3.1 CAMERAS

RED V uses two colour HD (1080P) USB cameras (Sony IMX323). These cameras were placed strategically on the bottom and the front overlooking the manipulator to ensure the pilot has a complete view of the ROV's surroundings. The bottom camera is mounted to make a picture mosaic of the Endurance Wreck. We used inexpensive Go-Pro cases (Figure 8) to waterproof our cameras effortlessly using resin. These cameras are connected via wet-link to the Bopla Bocube (waterproofing) and are connected to the Raspberry Pi.


Figure 8: Top & Bottom Camera Module

3.2 DEPTH SENSOR

We used depth sensors (Figure 9) to maintain our robot's altitude underwater, which improved the drivers' experience significantly. Furthermore, it helped complete precise tasks such as removing and replacing the buoyancy module and fixing the inter-ray cables swiftly.


Figure 9: Depth Sensor

3.3 ELECTRONICS / CONTROL SYSTEM

3.3.1 ON BOARD ELECTRONICS

Red V’s electronics have gone through two major iterations. The first iteration featured shoddy soldering, poor cable management, spade connectors, leaks and CNC horizontal plates, making the system almost impossible to repair. (Figure 11)

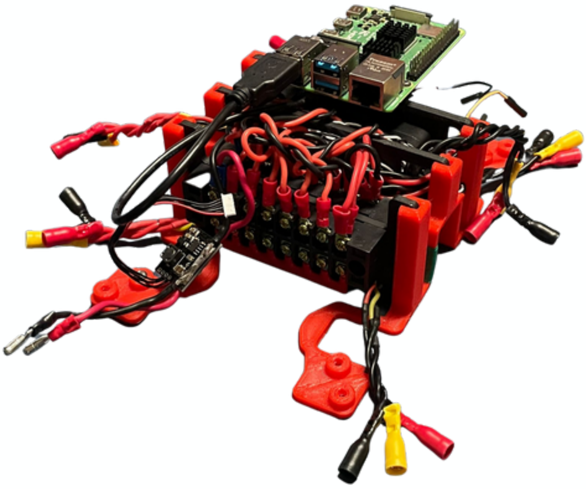
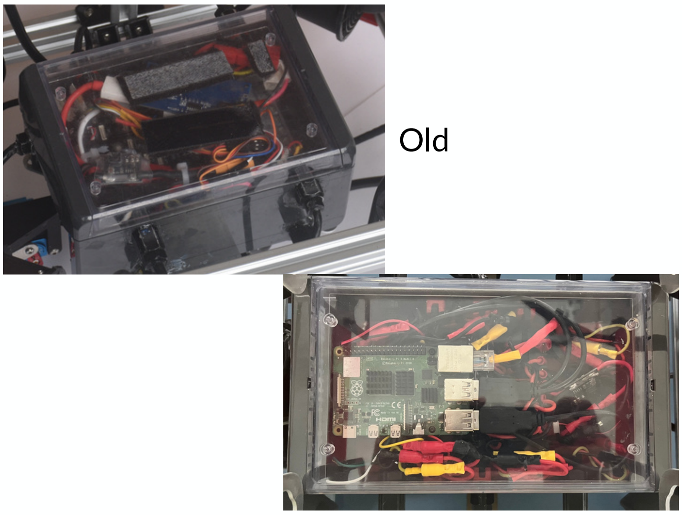


Figure 10: Internals of Onboard Electronics



Old

New

Figure 11: Old And New Electronics Box

While our new and improved version boasts a bigger, more spacious Bopla Bocube (210 x 191mm x 90mm), a weatherproof box, 3D Printed vertical plates and bullet connectors (Figure 11). We benefited the most from 3D printed vertical plates, which allowed us to slide out our electronics from the 3D Printed racks easily (Figure 10). Furthermore, 3d printing meant we could make minor modifications to these plates on a whim for cable management and changing positions of the components. This highly modular and customisable design made our second iteration extremely quick to build, taking only three days compared to 1 and a half months spent on the previous design.

Our central electronics system comprises of 6 EMAX Bullet ESCs (Small and low cost), Pixhawk 2.4.8, a Raspberry Pi 4B, power distribution terminals, two buck converters, depth sensors and two HD cameras (Figure 11). All wires entering the control station use wetlink penetrators for waterproofing despite their high cost ($18); our company decided to prioritise reusability for future teams and ease of use over traditional methods such as epoxy and cable glands. Additionally, all components are connected to their wires and each other using removable DuPont cables and bullet connectors for the ability to repair any part painlessly. (Figure 12)

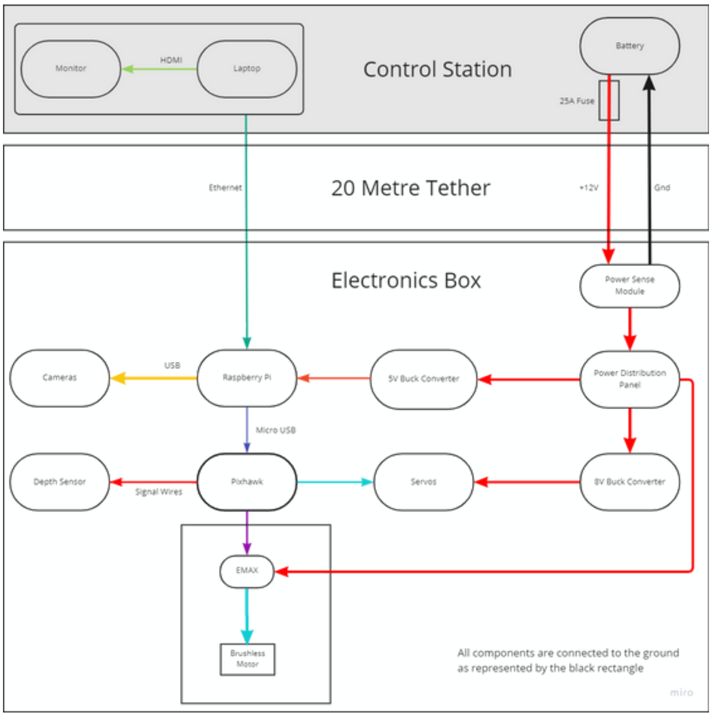


Figure 12: Electrical SID

3.3.2 TETHER

Our tether is exceptionally minimal, consisting of only two wires, an ethernet cable and a power cable (AWG 14), making the tether lightweight. Furthermore, The ethernet cable (which communicates with the raspberry pi) makes it more user friendly and quick to interface with the robot. AWG 14 wires help maintain a lightweight, flexible tether and reduce voltage drop to only 2.3V over 20m. Our tether also features a cable reel for cable management, ensuring safety at the location (Figure 13).

Figure 13: Tether Reel

3.3.3 TOPSIDE ELECTRONICS

Our control station features a PS4 Controller which allows for intuitive steering. Furthermore, we have buttons assigned on the controller to tune all axes, disarm, open, and close the manipulator to help effortlessly control the robot. The station also boasts dual monitors to display two camera feeds and vital robot information such as gyroscopic, compass, voltage and current data. Additionally, the station harbours an emergency stop button and tether relief (Figure 14).

Figure 14: Control Station

4. PROGRAMMING

4.1 BASIC CONTROL SOFTWARE

Our robot's essential functions, such as movement and manipulator, are controlled using the Ardusub system by Blue Robotics. This system utilises a raspberry pi as a companion computer, Pixhawk 2.4.8 as the autopilot (microcontroller) and a topside computer that acts as our control station.

4.2 PYMAVLINK

Since the ArduSub software only communicates using the MAVLink protocol, we used the Pymavlink library and, more specifically, the mavutil module to send MAVLink communications through python.

We used pymavlink methods to create functions for all movements (e.g. for upwards and downwards motion). We consolidated these functions into a single file to be called back simple import statements reducing redundancy from debugging and rewriting code.

Our company chose to use Ardusub as it is a tried and tested system with a vast community for support; this ensured limited points of failure in the future and less time debugging code. This decision was crucial for finishing the project on time.

4.3 ROV STATION DOCKING AUTONOMOUSLY

To perform the autonomous docking of our ROV, we implemented a timer, used the robot's internal compass and used the aforementioned forward function. We created a program with a loop that constantly got the angle (direction) at which the ROV was facing and kept turning the robot until it matched the predetermined direction of the docking station. Once aligned, using the 'multiprocessing' and 'time' libraries, we make the forward function into a process and allow it to run for a specific amount of time.

4.3.1 CAMERA CALIBRATION

For all programs which utilise the cameras, we first had to calibrate the camera stream to make sure that the resulting image is proportional, with the help of the pickle module.

Our front camera is a 180-degree fisheye camera and therefore undergoes barrel distortion, which needs to be corrected before any vision recognition can occur.

We did this using a chessboard with fixed heights and lengths, and we moved the board around at different angles. We passed this through cv2.undistort and stored the correction matrix using the pickle module. The differences in images can be seen below.

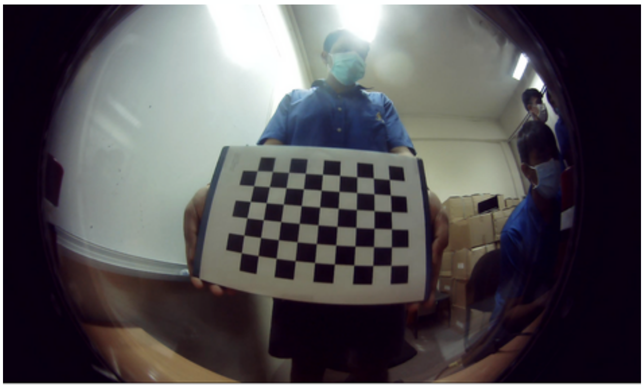


Figure 15: Difference in un-calibrated and calibrated image

4.3.2 RED TRANSECT LINE FOLLOWING

Using the OpenCV library and built-in modules, we could access the robot's camera stream and use colour grading and do contour detection using the cv2.drawcontours() functions. Using this data, we could locate the centre of the line; if the camera's centre is away from the centre of the line, the robot would use the motion functions mentioned above to automatically correct for it and continue following the line.

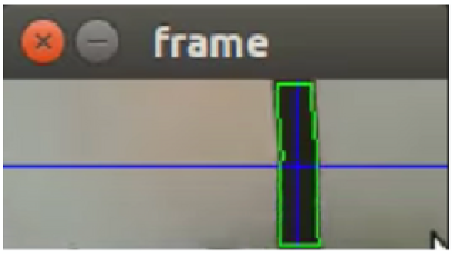


Figure 16: Open CV

4.4 'MORTS' DETECTION FROM COMPETITION VIDEO

To detect the morts from the live fish, we used YOLOv5, a popular machine learning algorithm for computer vision. We used 8 out of the 12 sample videos to create the dataset for the model. After training our model with this dataset, we detected any dead morts accurately and added a bounding box around them, and this was validated using the other two sample videos present. Additionally, to improve accuracy, we put bounding boxes on other objects (such as seaweed and nets) in the data set to more distinctly identify the fishes.

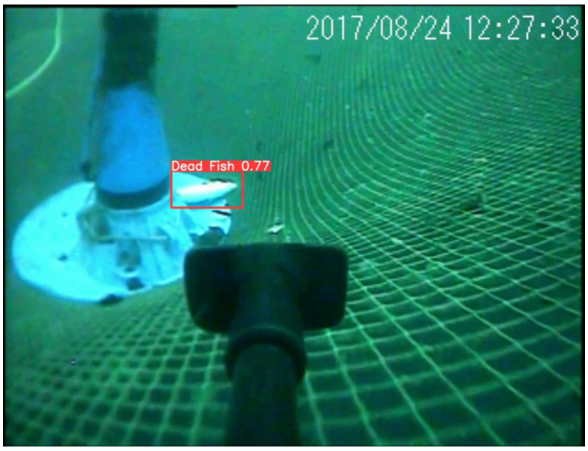


Figure 17: Mort detection

4.5 MEASURING THE LENGTH OF THE FISH AND WRECK LENGTH

We undistorted the front camera feed and used the inbuilt OpenCV function cv2.cvtColor() to isolate specific colours from the camera stream, and from that, we were able to create a bounding box around the fish and the wreck. The fish's width and the wreck's height are known values in real life and can be compared to the pixel values found from the bounding box. The ratio can be multiplied by the pixel length found by the camera stream to find the real-life lengths of the fish and wreck.

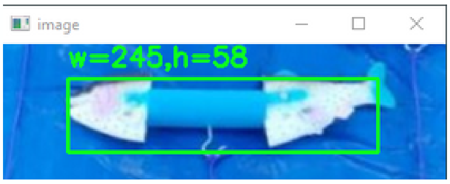


Figure 18: ROV measuring fish length

4.6 PHOTOMOSAIC

To create the photomosaic, the wreck photos given would be, firstly, added to the file with the code to create the mosaic. Then, we would stitch together two groups of four horizontal images using the cv2.stack() method. Finally, these two horizontal groups are stitched together, one over the other, to form a photomosaic of the wreck site.

4.8 GUI

We simply used the Tkinter library in python for our GUI due to its versatility and our team's prior experience with it. We have created buttons to start each task described above and an emergency stop button. Additionally, there are two camera streams. Below is a photo of the GUI without the camera streams.

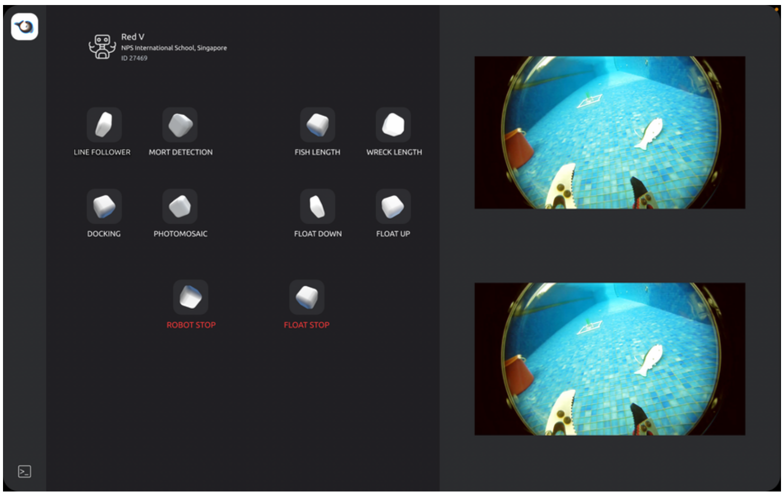


Figure 19: GUI

5. TESTING AND TROUBLESHOOTING

Testing and troubleshooting are some of the most crucial steps in building an ROV. However, given our time constraints, we had to plan our testing well in advance. For example, we tested for how long the Bopla Bocube was waterproof at a depth of 4m.

5.1 PIXHAWK AND THRUSTERS

We connected the Pixhawk, ESCs and thrusters outside the Bopla Bocube to eliminate the possibility of any broken components. Furthermore, we taped each connection to ensure they do not disconnect if any force was applied.

5.2 CAMERA AND RASPBERRY PI

We had to cut the camera wires to pass them through the holes in the Bopla Bocube. So, to ensure our connections were secure, we tested each camera independently and then both of them together with the raspberry pi. This was crucial to try as we had to ensure we could see underwater and complete the tasks.

5.3 MANIPULATOR

We tested the manipulator by connecting the servos directly to the Pixhawk and the laptop. We did this to ensure our servos opened and closed fully and turned 90˚. Furthermore, we directly connected the servos to an Arduino to ensure that our Pixhawk was not the issue.

5.4 WATERPROOFING

The robot was tested in a bathtub and a swimming pool to check for any leaks at various depths.

5.5 REFLECTIONS

5.5.1 VERTICAL ELECTRICAL PLATES

When troubleshooting our robot, we faced many problems in changing out the electronics parts. This was because of the large horizontal plate we had in our electronics box and poor cable management. Furthermore, it restricted access to the electronics near the base of the Bopla as well as made it difficult to close up the box when replacing components. One of the best changes we could have made was to switch to vertical plates earlier - they made replacing, troubleshooting and updating electronics components more accessible. One of the major lessons we learned from this was to plan out our actions better. Once we put real thought into the problem, we landed on the solution; and if we had just done it from the start, our ROV would have achieved its final form much earlier.

5.5.2 WETLINK PENETRATORS

When initially working on our electronics box, we decided on using wetlink penetrators to ensure the box's water resistance at the points at which the wires exited the box. This was an intelligent decision, but in hindsight, we made severe mistakes in applying these penetrators. Due to the aforementioned horizontal plate, after inserting the wetlinks, we had to remove them every time we needed to change something. The continuous removal and reinsertion of the penetrators led to their weakening, eventually compromising our ROV.

5.5.3 IMRPOVEMENTS

One of the most important improvements we would like to include is to add magnets to our manipulator, which would help us save time aligning the claw to the metal U-ring and the metal hook. Furthermore, we would like to include variable buoyancy with adjustable weights to achieve perfect neutral buoyancy.

We would also like to incorporate fundraising in the future so we have more flexibility choosing components and can better invest in our teams tools and resources.

6. SAFETY

6.1 SAFETY PROCEDURE

Here at ORCA robotics, safety is our utmost priority. We identify a possible risk in every task and thus take the necessary precautions to ensure the well-being of all members. We have a strict set of rules that every member of the company must adhere to at all times. First and foremost, safety goggles were worn when using power tools like drills and saws. All members were also required to wear closed-toe shoes at all times. We used safety masks when cutting dust-releasing materials or epoxying to minimise exposure to any hazardous substances. Our experienced CEO and CFO trained all recruits on how to operate all tools safely before they were allowed to use them. It was also necessary that we maintain a clean workspace at all times as this could lead to accidents like tripping over objects. We ensured that when using heat-releasing objects like soldering irons, the vicinity was free of any flammable substances and the tools were placed in an appropriate stand after use. Safety is also built into our ROV right from the early stages. See appendices x, y and z for the Job Site Safety Analysis and the Company Safety Review.

6.2 CHECKLIST

6.2.1 DURING CONSTRUCTION

- ☑ Closed Toe Shoes
- ☑ Hair tied back
- ☑ Refrain from wearing dangling jewellery or loose, baggy clothing near the robots.
- ☑ Safety glasses are worn when using power tools or soldering
- ☑ Rubber gloves and dust masks when using epoxy
- ☑ Air ventilation at all times
- ☑ Proper workshop behaviour (No running & safekeeping tools)
- ☑ Proper training on how to safely manage all tools
- ☑ Flammable objects stored safely in a flame cupboard
- ☑ Ensuring the powered tools are in good condition
- ☑ Chemical containers are properly labelled and in good condition with no sign of damage

6.2.2 PRE-MISSION CHECKLIST

- ☑ All items on the ROV are secured
- ☑ Cords and plugs free of broken insulation, exposed wiring, and provided with grounded connections, or double insulated

- [x] Strain relief on all wires
- [x] The main power switch is off until all electrical connections have been checked

7. ACCOUNTING

7.1 BUDGET

Our budget had to be carefully planned from the beginning of the design process as our company is not associated with a school or organisation. After finishing the CAD of our ROV, we mapped out and planned the list of components required for our ROVs construction and ensured that all components were at the lowest possible cost. We had approximately a total budget of USD$1492.30, all of which were sponsored by the families of the employees.

7.2 BUILD VS. BUY

Due to us being on a tight schedule, we found it best to 3D print the components instead of purchasing them in order to minimise costs and delivery time. Two of the company members had 3D printers and just required some filaments. The vertical plates in our electronics box holding the Pixhawk, ESCs and other components, were 3D printed, so we could get the perfect shape for us to remove the electronic plates from the electronics box without having to remove the wet-links attached to the sides of the box. the manipulator mount is also 3D printed, allowing us to have a custom design to suit our requirements without compromising on the weight of the ROV. As well as one of our improvements, the legs for the ROV were also 3D printed. These legs were used to prevent the ROV from resting on the bottom camera. The 3D printer worked best in this situation as we were on a time crunch and required the legs as soon as possible. The thruster mounts were also 3D printed as we could customise them to our specifications and virtually eliminate extra costs and delivery times.

8. PROJECT MANAGEMENT

8.1 SCHEDULING AND ORGANISATION

To ensure an efficient performance by every member, the team was divided into sub-teams with one leader for each. With everyone working on their respective tasks, productivity increased, and it ensured that each member committed the same amount of time as the rest.

For any documentation, such as the budget or attendance sheet, the company organised a drive folder (Figure 1) broken down into 4 broad categories of folders: general, technical, documentation and parts list. The general folder is for work not pertaining to any specific sub-team, such as the budget and attendance sheets.

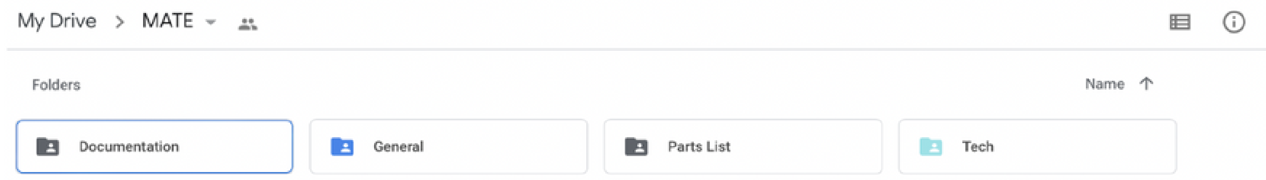


Figure 2: Our google drive and its sub-folders

In addition, all tasks were relayed through Trello, a project management software developed specifically for new users due to its gradual learning curve. There is one board for each subsystem on Trello along with a general tasks board (Figure 2). Respective heads assigned the tasks on these boards to the sub-team members (Figure 3). This software made it easy for the CEO and CFO to monitor the company's productivity as they could see what has been done, what is yet to be done and which members are assigned to the respective task.

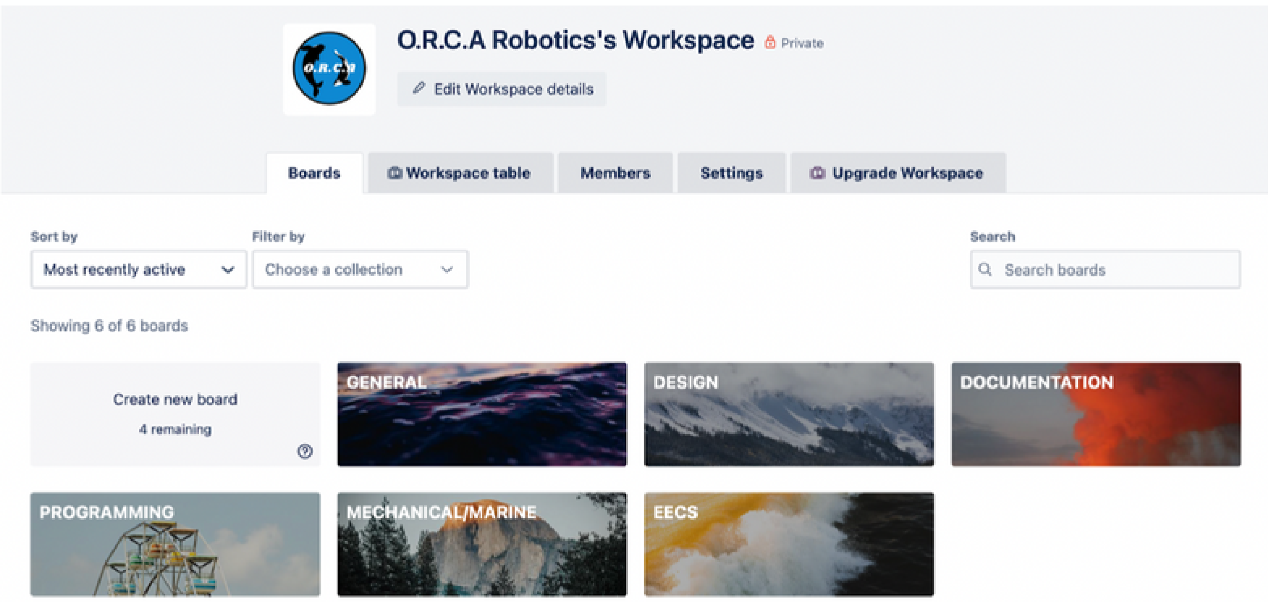


Figure 20: The boards on Trello

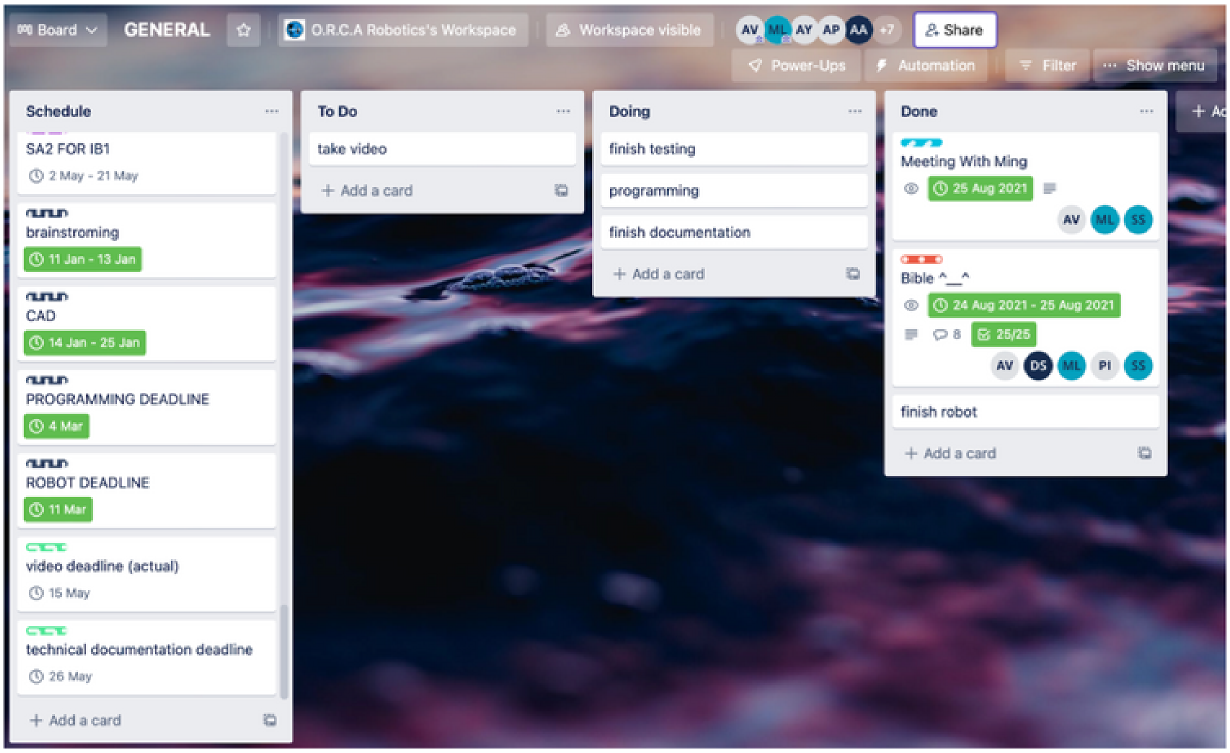


Figure 21: The task representation on our general Trello board

The primary platform for communication was Discord, where additional reminders or any discussions took place. When the build season (from January) started, the team would stay back almost every weekday from 4:15 pm to 6:00 pm to work on the ROV. Attendance of all members was maintained using an excel sheet, and general rules, such as 75% attendance, wearing safety goggles and proper use of tools and maintaining an appropriate workplace, were implemented on all the members. This way, the company members were productive, efficient and comfortable in the working environment.

8.2 WORK TIMELINE

This timeline shown in Figure 22 was made by the CEO and CFO in the early stages of development and illustrated to the company what the next few months were going to be like. From September to December 2021 we focused on skill building (learning programming, operating power tools, etc) of the new entrants through weekly sessions and the build season formally began in January 2022.

However, we soon ran into deadline issues during the build season as we were unable to account for school sports teams practices and our employees' personal engagements (e.g. dentist appointments). Additionally, we ran into unpredictable errors while forming the electronics like cable management and loose connections. Our wires were constantly stretched and tangled due to poor cable management, our soldering was shoddy with wires getting constantly disconnected. Even though these issues delayed our build season, additional commitment from our employees helped us overcome the time deficit.

	A	B	C	D	E
1	**Month**	**Specific time-periods**	**Events/Activites**	**Extra Notes**	Holidays
2	**August**				Breaks for exams
3		9th-16th	Selecting entrants		11th Exam Periods
4		23th onwards	start breifing and finance		9th grade exam periods
5		30th	CAD skill building starts		final deadlines
6	**September**	13th	CAD skill building paused		
7		14th - 20th	break for UT		
8		20th - 29th	UT-1		
9		27th	SA-1 for ninth		
10	**October**	6th	SA-1 for ninth over		
11		7th	CAD skill building resumes		
12		30th	CAD skill building over		
13		23rd	holidays start		
14	**November**	9th	holidays over		
15		1st-14th	Programming skill building		
16		15th - 22nd	break for SA		
17		22nd - 1st dec	SA-1		
18		22nd - 26th	UT3 for ninth		
19	**December**				
20		1st - 15th	mechanical skill building		
21		16th - 31st	progamming skill building		
22		16th	Holidays start		
23	**January**	7th	Holidays over		
24		11th - 14th	brainstroming		
25		15th - 25th	CAD of robot		
26	**February**	whole month	build season		
27	**March**	whole month	build season		
28	**April**	9th	build season over		
29		9th	testing begins		
30	**May**	10th	testing over		
31		15th	video demo duedate		
32		26th	techincal documentation		

Figure 22: Our Work Timeline

8. ACKNOWLEDGEMENTS

ORCA robotics would like to thank all of its members for the time and energy they spent on this project. Furthermore, we'd like to thank their families for their unconditional moral and financial support.

- We would like to thank our school Principal, Mr, Kris Bhatt for his support and guidance throughout the project. He also facilitated the process for us to get our own room, entirely dedicated to robotics.
- We would also like to thank the SAS robotics team, their robotics program has more experience, and they supported us while we faced difficulties and pointed us in the direction of the solutions. We would also like to thank them for letting us test our ROV in their school's pool.
- We would like to thank Jefferson Zhang for providing us with props for the regionals
- We would like to thank our Design and Technology lab teachers for letting us use their equipment when we ran into trouble.
- Last and most importantly we would like to thank MATE for providing us this incredible opportunity to expand our knowledge and designing and building by hosting the ROV competition.

10. APPENDICES

SCHOOL: NPS INTERNATIONAL SCHOOL
MENTOR: MR. KRIS BHATT

10.1 APPENDIX A - BUDGET

Source	Amount
Money from Company Members	$1484.51

Category	Type	Description / Examples		Projected Cost	Budgeted Cost
Safety	Purchased	Goggles	Safety Goggles	$24.60	$24.60
Hardware	Purchased	Aluminium	Aluminium Stocks, Corner & Angular Gussets	$61.60	$61.60
Electronics	Purchased	Electronics Board	Raspberry Pi 4, Pixhawk	$144.48	$144.48
Electronics	Purchased	Electronics Box	Bopla bocube	$107.36	$107.36
Propulsion	Purchased	Thruster System	8 Thrusters	$374.05	$374.05
Propulsion	Purchased	ESC	7 ESC	$112.79	$112.79
Sensors	Purchased	Depth Sensor	Depth Sensor	$94.64	$94.64
Sensors	Purchased	Camera	Sony IMX323 and Sony IMX322	$141.15	$141.15
Hardware	Purchased	CNC Parts	Electronics Mount, Manipulator Parts & Buoyancy Mounts	$108.57	$108.57
Mission-Specific Features	Purchased	Servos	25kg Power HD Servos	$65.70	$65.70
Electronics	Purchased	Wetlinks	Compression gland cable penetrator	$164.25	$164.25
Mission-Specific Features	Purchased	PLA 3D Printer Filament	2 PLA Black 1kg 3D Printer Filament	$34.89	$34.89
Hardware	Purchased	PVC	PVC pipes, end caps and pipe clamps	$50.44	$50.44

Total Income	**$1484.51**
Total Expenses	**$1484.51**
Total Funding	**$0**
Net Total	**$1484.51**

11. APPENDICES

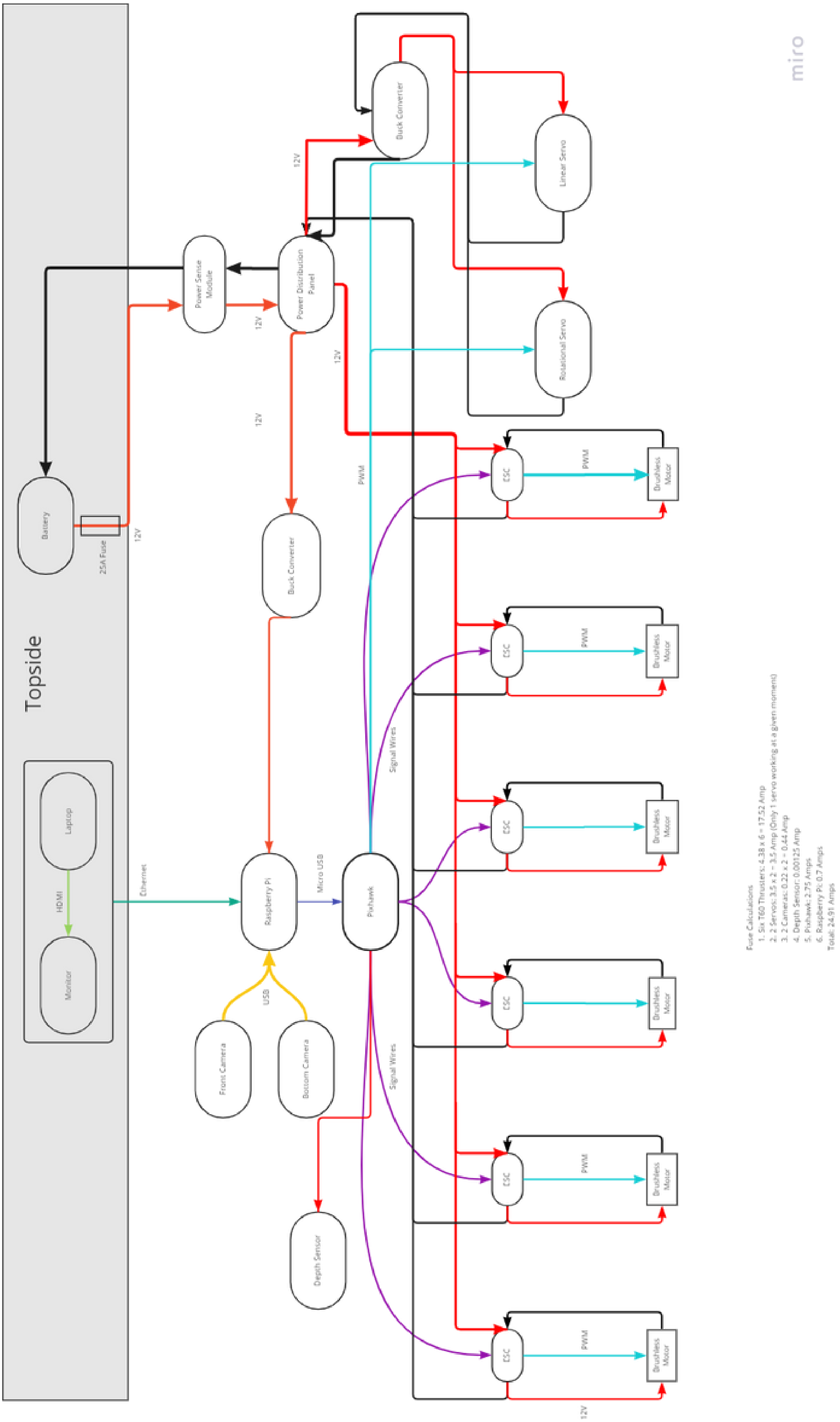
SCHOOL: NPS INTERNATIONAL SCHOOL
MENTOR: MR. KRIS BHATT

10.2 APPENDIX B - PROJECT COSTING

Category	Type	Expense	Description	Notes	Amount	Running Cost
Safety	Purchased	Goggles	Safety Goggles	For safety while using power tools	$24.60	$24.60
Hardware	Purchased	Aluminium	Aluminium Stocks, Corner & Angular Gussets	Used for frame	$61.60	$86.21
Electronics	Purchased	Electronics Board	Raspberry Pi 4, Pixhawk	Used for control system	$144.48	$230.67
Electronics	Purchased	Electronics Box	Bopla Bocube	Hold all the electronics	$107.36	$338.0338
Propulsion	Purchased	Thruster System	8 Thrusters	Used for thruster system	$374.05	$712.0858
Propulsion	Purchased	ESC	7 ESC	Used for thruster system	$112.79	$824.87
Sensors	Purchased	Depth Sensor	Depth Sensor	Used for thruster system	$94.64	$919.51
Sensors	Purchased	Camera	Sony IMX323 and Sony IMX322	Used for camera system	$141.15	$1,060.65
Hardware	Purchased	CNC Parts	Electronics Mount, Manipulator Parts & Buoyancy Mounts	Used to hold the electronics box and PVC pipes, and for the claw	$108.57	$1,169.23
Mission-Specific Features	Purchased	Servos	25kg Power HD Servos	Used for the claw system	$65.70	$1,234.93
Electronics	Purchased	Wetlinks	Compression gland cable penetrator	Used for waterproofing	$164.25	$ 1,399.18
Mission-Specific Features	Purchased	PLA 3D Printer Filament	2 PLA Black 1kg 3D Printer Filament	For 3D printing	$34.89	$1,434.07
Hardware	Purchased	PVC	PVC pipes, end caps and pipe clamps	Used for buoyancy	$50.44	$ 1,484.51

Total Income	**$1484.51**
Total Expenses	**$1484.51**
Funding Needed	**$0**
Net Total	**$1484.51**

11.3 APPENDIX C - COMPLETE SID



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