TECHNICAL REPORT

Vijay Sambamurthy
CEO

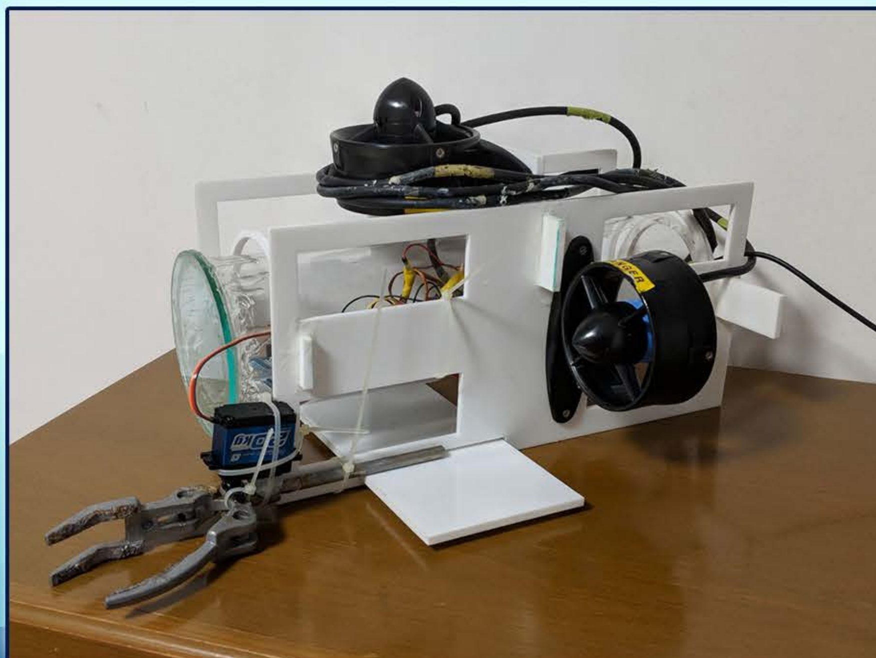
Nono Tseng
Safety Officer

Johnson Oh
Testing Manager

Dhananjay Rao
R&D Director

Nikhail Wadhwani
Technical Writer

Rahul Arya
Lead Engineer
Year 13



Riccardo Caiulo
Director of Manufacturing

Michael Yung
Technical Writer

Ismet Ozer
Director of Finance

Ernest Yip
Logistics Manager

Jayesh Chatlani
Technical Writer

DROWNERS

KING GEORGE V SCHOOL

HONG KONG

MENTOR: MR.CROCE

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<u>Team Roles:</u>

Vijay - Chief Executive Officer

Rahul - Lead Engineer

Dhananjay - R&D Director

Ismet - Director of Finance

Riccardo - Director of Manufacturing

Ernest - Logistics Manager and Engineer

Nono - Safety Officer

Johnson - Testing Manager

Jayesh, Nikhail, Michael - Technical Writers

Abstract

For as long as underwater exploration has existed, mankind has always wanted to explore the deepest regions of the ocean without risk to the life of human beings, necessary for the piloting of such vessels. The creation and development of underwater drones have been an incredible step for human exploration, and will without a doubt bring more and more knowledge to the minds of scientists wanting to know more about the animals that live in these unexplored parts of the ocean, and to the minds of engineers who strive to develop faster, stronger and more versatile drones in the effort to bring mankind one step closer to absolute observation of the seas.Our remotely operated vehicle (ROV), Corion, is constructed around a waterproof acrylic tube that houses the Corion's on board electronics and systems. The Corion is propelled by three brushless motors. Two are attached to the side frames to control forward and backward movement as well as horizontal rotation, and one is secured horizontally on the top frame to control up and down movement. These three high power thrusters enable a strong acceleration in situations where time is a factor. Corion is also equipped with one digital camera that offer the pilot on the surface a view of Corion's surroundings. Keeping the minimal yet innovative design in mind, we are confident that the Corion is ready to face any challenge it will be presented with.

Company Mission

Due to the rapid advances in aeronautical and mechanical engineering, as humans we now can explore the depths of the harshest environments of the planet. At the KGV UR team, a fundamental goal that we value is prioritizing innovation and minimalism. Our robot Corion, was built to conduct a series of functions built on the premise of expanding humanity’s knowledge of our world, designed to collect samples, recover lost items and analyse important data vital for our understanding. With its simple design and innovative features, we have constructed our robot to meet the MATE ROV specifications and operate under harsh marine environments.

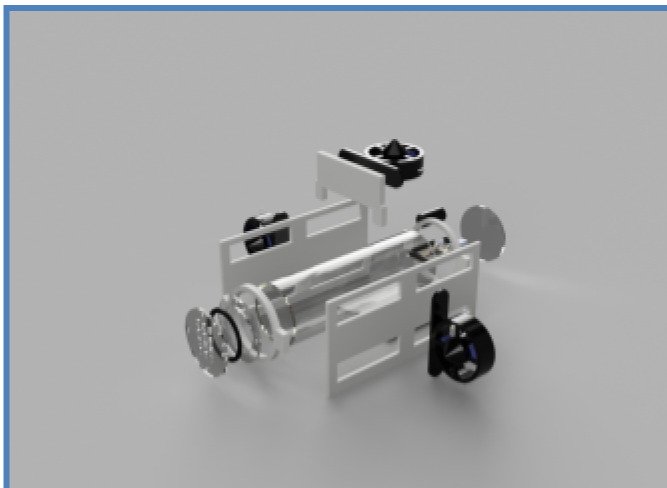
Build Vs Buy, Reuse vs New Decisions:

During the creation of the ROV we had to make decisions on whether to build or buy certain items. We hoped to build most of the components and only purchase those we deemed absolutely necessary, to save money. Below is a list that we made which includes the equipment that we have bought or have built.

Item	Bought/Built	Reused/New
Motors	Bought	New
Frame	Built	New
Clamp	Built	New
Electronics (wires,boards,Arduino,etc)	Bought	New
Control Box	Built	New
Camera	Bought	Reused

Some of the essential parts of the ROV had to be bought, such as the Arduino, the motors and the camera. Although building them would have been great projects on their own, it would have cost too much money, time, and effort to build them from scratch, so buying them was essential. However, we chose to build everything if we felt we could make them more efficient and customizable. This included the frame, the clamp and the control box. All these things had a relatively simple design but it was important that they were built, as they worked together a lot more efficiently and smoothly when custom-built together instead of purchased separately.

However, even when we had to purchase the items, we tried to re-use as much of the equipment as possible, as we did not want to purchase them new when existing components were still in perfect condition. This not only reduced the cost to build this by a huge fraction but it also benefits the environment as we are re-using the equipment that

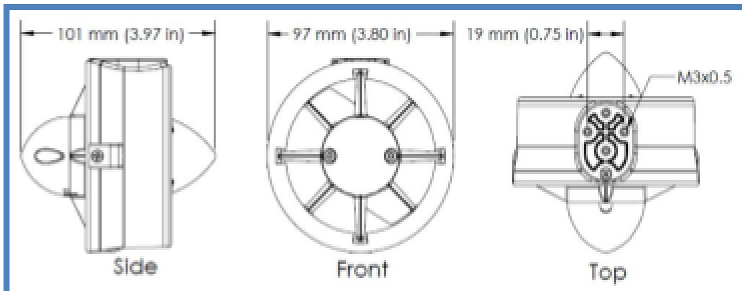


Exploded view of Corion

we have. The only major component that we did not reuse was the motors and the overall framework for our design, we needed newer and better motors as the old ones have started to rust and are not strong enough to withstand the new design. And the new frame is because we wanted to learn and improve from the previous team that competed in this competition and see what areas needed to be changed for us to achieve a better quality ROV.

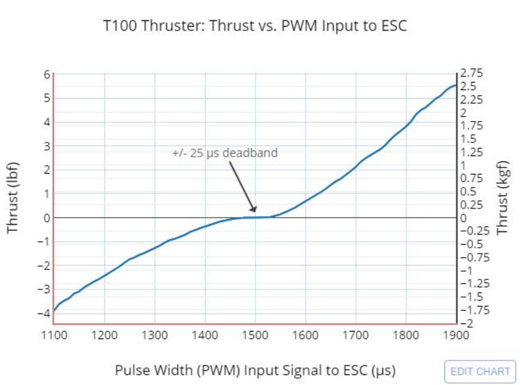
Design

The design of the ROV was made with the safety and security of the hardware as the top priority. As you can see in the following pictures, most of the hardware is cased within a cylindrical transparent acrylic container, kept safely water-proof by acrylic lids stuck on using epoxy. The water-proof container is also extremely resistant to pressure and damage by physical objects as the force applied is distributed evenly along its surface. Moreover the translucent design allows for instant view of the encased electronics, ensuring a very expedited and efficient diagnosis of any system damage that might occur in the event of the inside electronics getting damaged.



Dimensions of T100 Motors

The motors were placed in strategic positions around and above the ROV, ensuring access to the application of force on all 3 axes and a clear path for the water to go to after being pushed by the motors, increasing the efficiency of use of the energy supplied to them. The Corion uses T100 Thrusters, an affordable option for thrusters, providing 23.6 N of forward thrust. The casing of the motor is designed to be durable, made out of high strength UV resistant polycarbonate injection molded plastic. The core of the motor is sealed and protected with an epoxy coating and uses high-performance plastic bearings to prevent from rusting. In addition, aluminum and high-quality stainless steel is used for parts not made from plastic to ensure that the thrusters do not corrode. The T100 Thruster posses a specially designed propeller and nozzle, providing an efficient, powerful thrust with active water-cooling utilised to help cool the motor. The thruster is simple to control and the interface only requires the user to connect the three motor wires to brushless electronic speed controller (ESC). This allows it to be controlled with an RC radio or a microcontroller. The T100 Thruster can also be controlled with an Arduino Mega, which we used to control it. These thrusters were powerful, but without



intelligent placement they would be useless, so we made sure to calculate where the centre of mass was for the ROV and place the motors accordingly, so as to maximize the percentage of force used and the torque in case of rotation. Furthermore, we made sure that the motors were placed in locations that wouldn't impede the function of the clamp and/or the lift bag.

The wiring is kept in neat bundles by zip ties, ensuring that while in operation, the ROV does not accidentally damage or tangle the wires. The number of wires was also kept at a minimum during design, making sure that only the bare minimum was connected to the control board. Consequently, we have minimized the chance of the wiring being damaged during a mission while also decreasing the chance of it getting cut off or destroyed by a scuba diver.

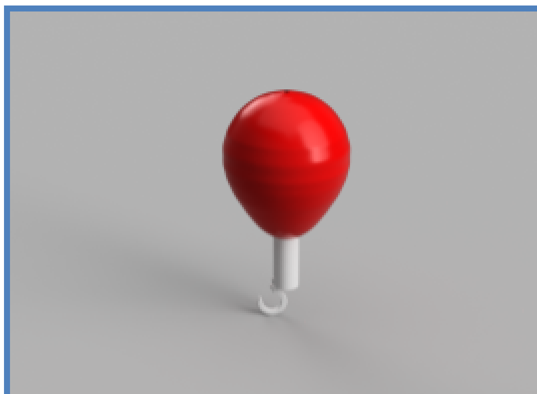
The claw was designed with simplicity in mind but is able to grasp objects with a large amount of force, guaranteeing that the object will not fall from the grip when the ROV is in action. Due to its simplicity, we believe the chance of a failure to be rare due to the lack of points of failure. Even though this clamp is a modified science experiment clamp, it is built with a rubber surface on the inside which will increase the friction in between the object and the clamp and thus increase the grip. The blue box as shown by the image is a digital servo, which controls the actual movement of the clamp. That servo can grip with a torque of 20 kg-cm, which is more than enough pressure to firmly grasp objects underwater.

Rendered Image - Claw

The Lift Bag is a crucial part of the ROV. It is the component made to lift objects in one direction, and applies the most force out of all the equipment we have on the ROV. The Lift Bag is an assembly of different parts which work together to generate a large amount of force to bring an object up

$$
\begin{aligned}
\Sigma F &= F_{bottom} - F_{top} \\
&= Ap_{bottom} - Ap_{top} \\
&= A\left(p_{atm} + \rho g y_{bottom}\right) - A\left(p_{atm} + \rho g y_{top}\right) \\
&= A\rho h g = \rho V g \qquad \text{direction up}
\end{aligned}
$$

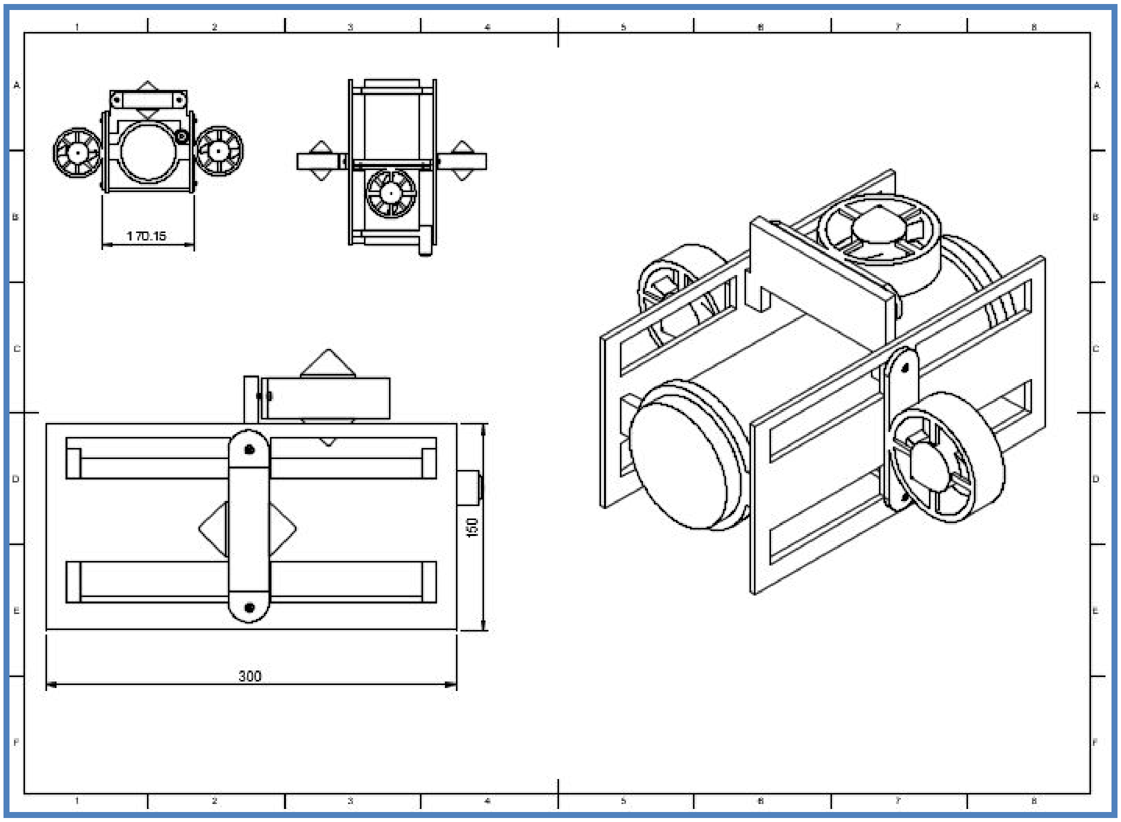
Archimedes Buoyancy Equation



Rendered image - Lift Bag

for ease of transport. It works in this fashion: The hook catches onto an object, and at the same time air is pumped manually through a bendable tube connected to an air-tight bag attached to the hook. The tube runs from a manually operated pump on the surface along the tether. The ROV's claw then releases the lift bag, which carries the attached object up to the surface.

Below is an image depicting the 2D designs made for the ROV (measurements in mm):



Testing Protocols

We have created a testing protocol to guarantee that the operation functions safely. Members of Drowners are required to first test the Corion on land, during this systematic dry run unforeseen problems can be easier to solve in air than underwater. Drowners conducted dry run testing multiple times, testing the Corion for errors in its electronics, including the motors, cameras and manipulator claw. The motors were able to respond accurately to the command of the control interface and produce the desired thrust. The cameras were operational with accurate real time footage relayed back to the pilot. The testing of the claw was a success as the claw was able to respond to the commands of the controller with a high degree of precision. Next we tested the servos, these operated without fault. We tested the claw by making it grab certain objects with a low friction coefficient. By detaching the camera from the

ROV, we also tested the camera at various depths to identify any problems. During the course of the dry run testing, members of Drowners adhered to testing protocol. For example, members were instructed only to touch the Corion when it is idle, preventing injury to the member. A member was also stationed near the power supply at all times, to ensure that in a case of an emergency the power supply is turned off to prevent damage to the Corion and injury to the members.

After conducting a dry run test, we reapplied waterproof insulation to the casing holding the electronics and proceeded to investigate any sources of leakage by creating a smaller scale replica of our electronics housing. The results showed no signs of leaking into the main case. We also re-evaluated the design of our casing using 3D cad modeling software to show potential stress points and underwater resistance. Based on this analysis, we concluded that our design was satisfactory for our purposes, though we hope to make our design more resistant and hydrodynamic in the future.

We then conducted underwater testing in a 90cm x 60cm x 50cm water tank. The reasons behind this was to ensure that the Corion can be quickly removed if any problems occured reducing the risk of damage to the electronics. The cameras, clamps and motors were tested. Results show that all electronics were functional and operational. Furthermore no leaks were discovered. We then transferred the Corion into a 25m swimming pool to test its maneuverability and movement speed along with the gripping ability of the clamp. The Corion gained satisfactory results in its maneuverability and speed. The clamp of the Corion was also able to grip securely on object underwater and carry them successfully to the surface. Overall, the underwater test showed the Corion was able to complete a large number of its designated tasks.

Time Management

The team was extremely efficient when it came to timing, working in just one month to design and build the ROV. To make sure the time we had was being used as efficiently and diligently as possible we kept a schedule for weekly meetings, and established a plan for the construction of the separate parts of the ROV. Below is a Gantt Chart portraying our schedule.

Tasks	18/02-24/02	25/02-03/03	04/03-10/03	11/03-17/03	18/03-24/03	25/03-31/03	1/04-7/04	8/04-14/04	15/04-20/04
Designing the Electronics									
Designing the Casing:									
Manufacturing of the Casing									
Assembling the robot									
Testing the Robot									
Making Final Adjustments									

These are the subtasks in each main task we needed to complete:

Designing the Electronics:

- Connect the thrusters, servo, and underwater cameras to an Arduino Mega for initial electronics testing
- Order necessary components for later integration

Designing the Casing:

- Use Fusion 360 to draw and model the exterior casing structure
- Design a casing which is waterproof

Manufacturing of the Casing:

- Use the laser cutter to cut the shape out of casing on acrylic
- Explore different equipment which can provide a strong structure
- Cut the correct length of acrylic tube
- Use epoxy to glue the casing together

Assembly

- Add the electronic inside the O-ring tube
- Add the claw design onto the frame
- Adding floats onto the vehicle

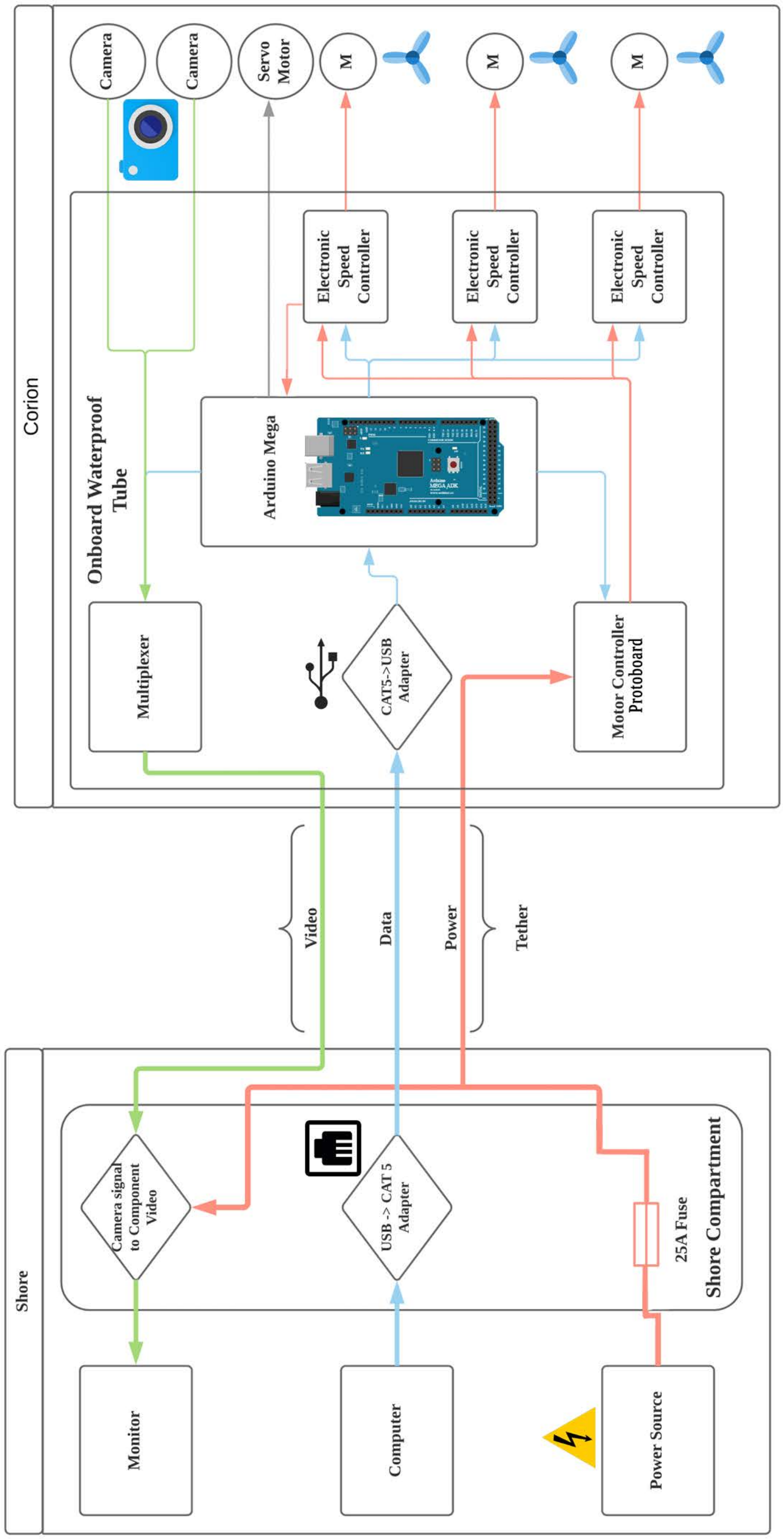
Testing

- Test the robot underwater to see if it can withstand the water pressure
- Check if all actions can be performed effectively

Final Adjustments

- Adding extra strength to the structure by using epoxy
- Cover sharp corners
- Labeling dangerous equipment

Systems Interconnection Diagram



NO FLUID POWER IS USED ON THE ROV

Materials Used

The team used a large amount of materials to build the entire robot, but aimed to keep expenditures at a minimum to ensure that the total cost was kept within the school budget of 2000 HKD. For the overall frame we decided to use acrylic as the main material with which to make the frame as it is transparent and yet very structurally stable. Due to the tube being transparent, if any damage is caused to the internal processors or electronics the damage can be observed easily and we can therefore decide on a good plan of action to repair it without having to pull apart the entire chassis. Another benefit to acrylic is that it is widely available and also relatively cheap. In total, we used a cylinder of acrylic with a 5 cm radius as well as 2 A2 sheets of 6mm acrylic. We used 6 tubes of epoxy to attach all the different components together, along with 10 metal screws, and three T100 motors. We also used a water-proof camera and a 10 meter tether. Finally, we used a plastic bag and a metal hook for the Lift Bag, and a servo motor along with a metal clamp for the claw.

Electronics Summary			
Item	Current (A)	Quantity	Total (A)
Thrusters	5.0	3	15.0
Camera	0.06	3	0.180
Arduino	0.026	1	0.260
LED	0.2	1	0.020
Motor Controllers	0.05	3	0.150
Servo Motor	1.0	1	1.00
Total	-	-	16.376

In order to get the correct rating of fuse, we did a worst case scenario measurement where we multiplied it by 1.5, to see what the robot would be pulling at 150%, this resulted in a total Amperage of 24.564. Hence, we decided that the best fuse for this **would be a 25 AMP rated fuse.**

Costs:

Item	Cost (HKD)
O-Ring Seal	89.94
Servo Motor	323.47
Stripboard	149.70
3 T100 Thrusters	3360.96
Epoxy	52.00
Acrylic (A2 Sheet + Tubing)	300.00
Arduino Mega	320.00
Tether	200
Other Expenses	303.00
Total	**5099.07**

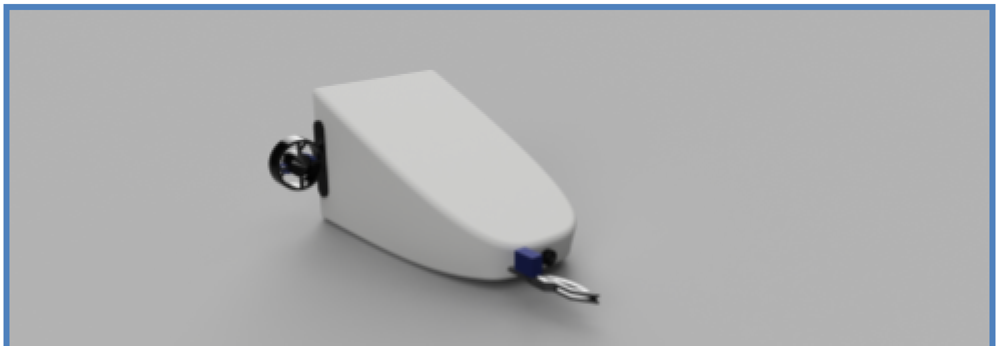
We had a limited budget and therefore we had to maximise the amount of resources we could buy with it. We made as many of the parts as we could in the limited amount of time we had. When we required items that we could not manufacture ourselves, team members visited a range of stores to identify the cheapest possible prices, whilst also checking online to ensure that we were getting the best possible prices for the items. For example, while sourcing the motors, we looked on multiple different websites and sent members to Mong Kok to try to find the cheapest alternative, ultimately ordering the motors from Blue Robotics. To source raw materials for the frame we again sent some of our members to Sham Shui Po to obtain sheets of acrylic thereby ensuring that we kept costs to a minimum. We had a budget of 2000 HKD provided by the school. To stay within this range we made sure to always keep our expenditure at a minimum and only purchase what was absolutely necessary. Despite this, we still went over the 2000 dollar limit and had to divide the cost equally amongst the members of the team.

Alternative Design

The images (right and below) show the alternate design we had considered for our ROV. The benefits of this over our chosen design was that the

Rendered Image- Alternate Design

onboard systems would be enclosed inside the casing, which would make the robot more durable and able to withstand potentially more dangerous environments. However, there are only three motors present and the unorthodox shape of the ROV would decrease its mobility and its capacity to move up and down. In addition, the only way for us to create this would have been to use the 3D printer available to us at school. The materials available for us to use would not be strong enough and after sealing the product, it would be difficult for us to change anything after the testing period if necessary.



Rendered Image - Alternate Design

Mission Completions

In order to successfully complete our missions we have devised a plan for each one such that we complete with utmost efficiency. To start, for the Aircraft, we have written a program in Python to complete the data collection and thus give us details about the aircraft and search area. Once we have this completed, we will launch our ROV (with the lift bag attached) and hook the lift bag to the debris by maneuvering our robot. Once the lift bag is attached, we will use our manual pump to inflate the balloon inside and thus move the debris from the area. Then, our ROV will once again grab the lift bag and disconnect it from the debris.

For the third mission, we plan to use Corion’s claw to manipulate various props within the pool. With one camera oriented towards the claw, the pilot should be able to easily position and align the ROV before grasping props with the manipulator.

Sanding Part of the Acrylic

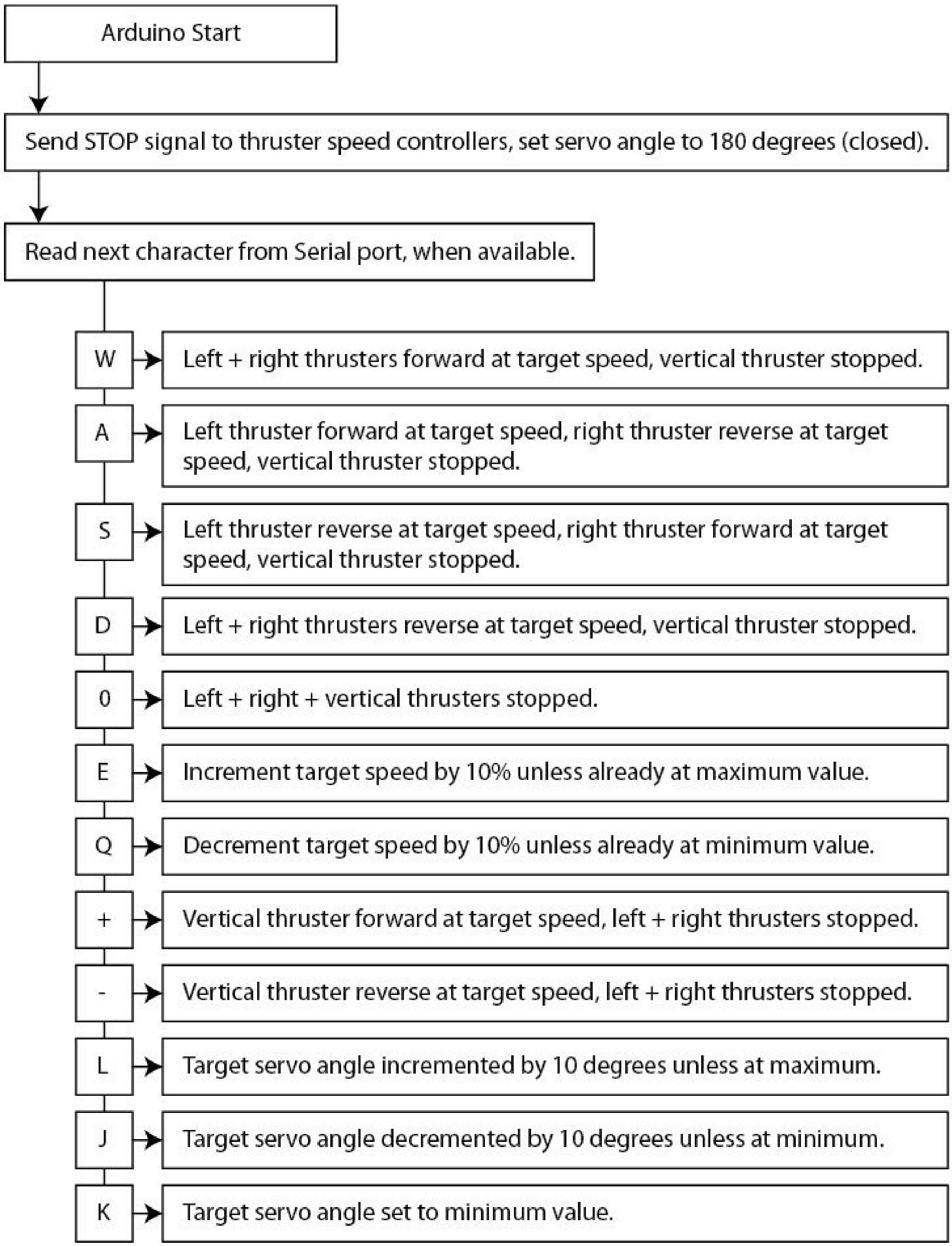
Safety Overview

During the construction of our robot, we followed many safety procedures which included wearing safety goggles when using power tools. When we handled power tools such as soldering irons, and saws during the construction of other parts of the ROV, safety goggles and aprons were worn. Drowners are pleased to report that throughout the construction phase, the Safety Officer was pleased with the safety standards which were satisfactorily met and reported no violations of safety protocols. The frame of our robot was created by laser cutting sheets of acrylic which was a computer process. To minimize the risk of injury, we used red coloured tape to indicate sharp edges on our robot as a form of a visual safety aid, with yellow used to indicate moving parts. We used cobalt chloride paper, placed within the watertight enclosure, to test if the robot was waterproof. When water is present the cobalt chloride paper turns from blue to pink. The cobalt chloride paper was just a first check whether the robot was waterproof, and we did a final check by testing it in a swimming pool.

Summary of safety features in the ROV and controller base:

- Shrouded motors
- Yellow tape on moving parts
- Icons around cables to indicate high current
- Calculated and correctly rated fuse (25 Amps)
- Rounded corners to prevent cuts and damage to wildlife
- Bright indicators on ROV for easy distinguishment

Arduino Onboard Software Flowchart:



Conclusion

Challenges Faced:

The team faced many challenges during the design and manufacture of our ROV. For example, making the cylindrical container completely waterproof took many attempts and coatings before it worked. In addition to this, whilst sealing the parts of the main frame together, the parts were difficult to all epoxy together without potentially changing the structure of the assembly, so teamwork and precision were needed to ensure a precise and even distribution of epoxy resin seal.

Reflections:

Every member of the team was faced with specific challenges that were to be solved diligently if the success of the team was to be ensured, and I believe that every member of the team did so; however we all have areas of improvement and aspects of the process that we didn't enjoy. Hopefully the experience was positive and generated a more profound initiative to learn for every member of the team. The following reflections outline what we found difficult, what we enjoyed, and what we aim to do after the competition is over.

Riccardo:

"The process of creating the ROV was very arduous for every member of the team, however the incredible efficiency and restlessness of the team always made up for it, and we always managed to handle difficulties in both design and execution of the plan, the management of completing the write-ups, purchasing materials and other delegations. For example, when we were deciding on which aspects of the original plan to bring over to the new we had to decide which were important and which we could afford to lose. This experience has not only given me an opportunity to work with other people on a project we all were passionate about, but it developed my ability to communicate about many technical aspects of the ROV with other people. Regardless of the outcome of the competition, I wish to do independent research in the areas of electronics and underwater exploration. Hopefully next year our team will return to this competition."

Vijay:

"Even though we had found out that we were entered into the competition just around a month ago, it still surprises me that the Drowners team were able to make such an amazing product within such a short span of time in addition to all the halts they faced. There was effort

from everyone all through the process of creation, while the endeavour is still not over, I believe that it was truly a learning experience. For example, when we were printing the various parts on sheets of acrylic we only had a limited amount, these constraints made us think carefully about how we were going to use it and balance the advantages of each part. Not only have I gained knowledge on the safety precautions that underwater robotic teams have to go through, but also earned myself a hole new viewpoint when it comes to teamwork. The robot itself is something beautiful. At first, I expected a immobile brick to be the outcome, however, I knew deep down, that the team would prove me wrong. And thus, efforts have been put in to make a functional robot that can complete tasks. The thought put in from the plethora of students has really been a huge advantage and truly one of a kind."

Johnson:

"During the construction of the Corion, we faced difficulties and challenges in designing, manufacturing and purchasing. We had to decide what aspects of design would be carried over from old to new, what parts of the drone were absolutely necessary, what we had to buy or build, and how we were going to build the things we weren't going to buy. Despite this our team was able to overcome these minor problems thanks to the qualities of its members, they were efficient, communicative and persistence. Drowners possess a unique team, we have members from different backgrounds from computer science students to electronic students. I believe that it was from this diverse pool of talents that made Drowners such an effective team. Personally, I have gained a great deal of knowledge from the members of this team and this is what I find the most important, the competition is just an opportunity of us to learn, regardless of the outcome of the competition. I believe that from our experiences next we can return even more successful."

Ernest:

"As logistics manager, I was in charge of the material sourcing of our robot - finding the best materials possible for our robot, organising and scheduling environmental friendly setup for the underwater robotic testing and also as constructing the robot as an engineer. I faced many challenges during the process of completing this robot. For example, when purchasing the parts for the robot, I had to arrange different members of Drowners to go to different shops to get different parts for the robot. While some had bought the parts required successfully, some came back saying there was no stock from the shops and had to wait. This delayed our estimated construction time and therefore shortened the time for the robot testing. For the robot testing, we tested it first in a bin filled with gallons of water, then went to the swimming pool for more precise buoyancy test. No materials were needed for the testing and it was environmental friendly and could be reused by others. We Drowners have been working consistently hard in the last month and were able to create a robot for the competition.

Personally, the competition allowed me to work with a group of new peers and gave me another opportunity to learn. What I took out of the competition was that no matter the number of people in the group, large or small, the group can be very effective if everyone contributes their part and tries their hardest to fulfill the team goals."

Appendix:

https://www.bluerobotics.com/store/thrusters/t100-thruster/

https://byjus.com/archimedes-principle-formula

https://hobbyking.com/en_us/power-hd-lw-20mg-servo.html

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