DROWNERS LLC.

“WHAL-E” Underwater R.O.V.

King George V School

Hong Kong Regional Round

Technical Overview and Design Document

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Special thanks to our advisor Mr. Gianluca Croce

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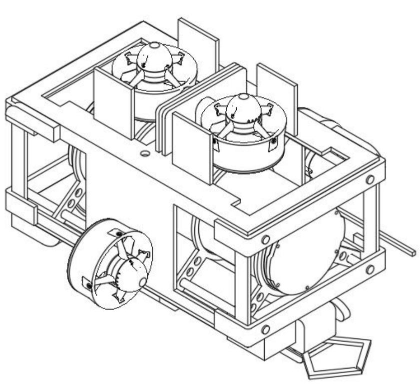
Abstract

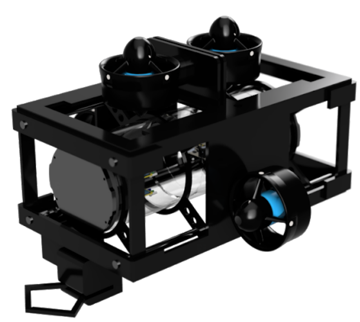
Successful robots are modular, functional and simple (at an appropriate level of abstraction). From the outset, *Drowners LLC* kept these core ideals in mind in designing this year's ROV (Remotely Operated Vehicle), *WHAL-E*.

WHAL-E's main electronics are housed within a cylindrical acrylic tube to ensure safety by ensuring it will not come into contact with the water. The curved surface of the tube additionally serves to reduce the water resistance induced onto the ROV. This is surrounded by an acrylic frame to further stabilise the ROV's stationary and kinetic motion. To complete the tasks specified in the MATE/Eastman joint proposal request, *WHAL-E* is equipped with two endoscope cameras to provide visual feedback, and is propelled by four T100 brushless thrusters that utilise a vectored thrust orientation to enable navigation.

The name *WHAL-E* was chosen to reflect both the specialised nature of our ROV (similar to its fictional namesake *WALL-E*) as well as its versatility and adaptability. We believe that this design will be capable of performing complicated multi-tier operations. The development of *WHAL-E* also reflects *Drowners LLC*'s principles of eco-friendly design, as evident in the modular nature of *WHAL-E*.

It is our hope that *WHAL-E* will be able to meet MATE's requirements, and hopefully give us a chance to showcase the product of many hours of hard work and collaboration from all members of our team.



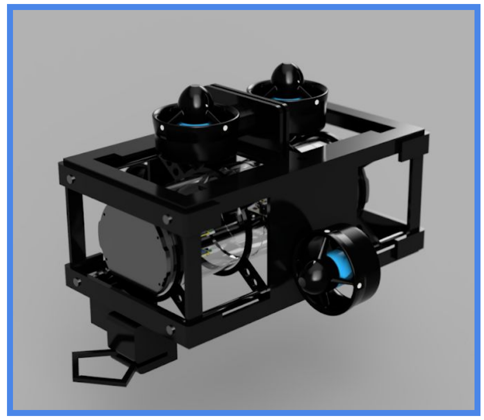


WHAL-E CAD Renderings in Fusion 360

Design Specification

The design of *WHAL-E* was made with the safety and security of components and personnel as top priorities. It consists in essence of five integral components: the frame, the claw, sensors, propulsion and the Command and Control (C&C) module.

Frame / Design Overview



3D View of ROV

WHAL-E primarily consists of a laser-cut acrylic framework, a central waterproof C&C module, four external brushless engine mounts, and an external remote operation terminal with a link cable connecting the ROV to the terminal.

Structurally, our ROV is supported by multiple intersecting acrylic boards connected via bracket pieces and screws, which provide an easily extensible and modifiable framework to suit the changing needs of the ROV through its multiple stages of operation. The central C&C tubule is connected to four concentric rings which are themselves attached to a cuboid frame, all cut from acrylic.

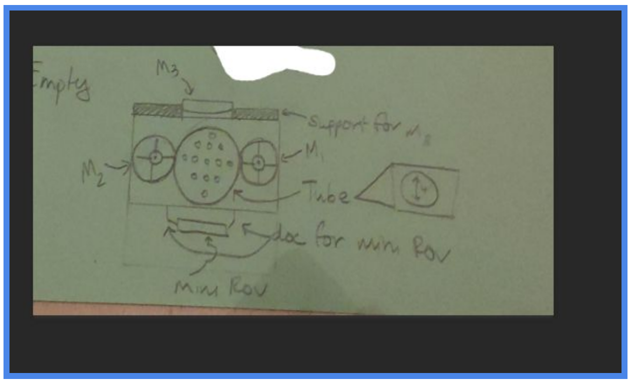
The choice of acrylic for the structural material provided a highly water-resistant and firm exoskeleton which could be used to attach components such as motors or tubing, while remaining flexible enough such that mistakes could be corrected without the loss of an entire framework that the use of welded metal or 3D-printed plastic would have caused. In our opinion, the slight cut in overall structural integrity in high water pressure environments would be offset by the versatility and adaptive potential provided through our choice of framework.

Development Legacy and Iterative Design

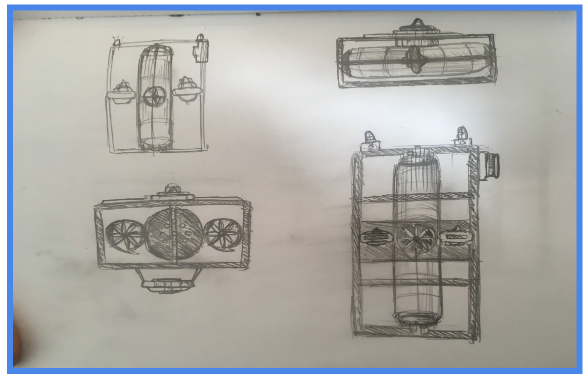
Waterproofing was a serious deficiency in last year's *Corion*. After weighing various options, we decided that the cylindrical watertight enclosure available from Blue Robotics would be a worthwhile investment, allowing our team to focus on solving specific, mission-related tasks while minimising worry about water leakage.

Given severe design issues that compromised last year's robot's structural integrity and exacerbated troubleshooting, *Drowners LLC* decided to start essentially anew on all aspects of design for this year's robot. As a result, we had to undergo several stages of rigorous iterative design to achieve our final product.

Below are rough sketches made early in the design process. These initial drawings demonstrate our vision for *WHAL-E*'s compact, minimalist and modular design.



One of the Proposed Initial Designs

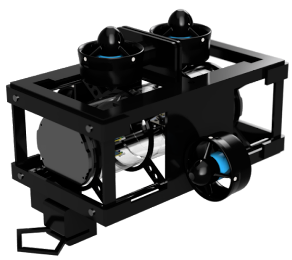


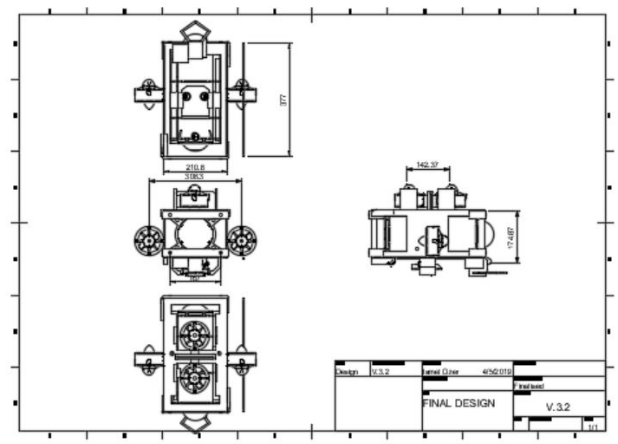
More Detailed Sketches

In order to develop the final design, every member of the group cooperated to pitch in ideas, with the best selected by the executive team for use in the final production prototype.

The initial ideas on paper were the starting point for computer-aided design (CAD), with the help of the software Fusion 360 (available without cost through our school's license). Our team members were initially inexperienced, but through significant internal collaboration, as well as consultation with teachers, we were able to turn the computer-aided design phase into a powerful resource when commencing the actual building. A variety of tools were used to model the exterior, including the sculpt tool to create the exterior of the model and the pull-drag tool to create holes in our 3D Design. We also downloaded component 3D CAD models to add to our design online. By adding all the component pieces onto the design, we were able to visualise what our intended robot would look like and by scrutinising dimensions, we were able to make sure that our laser cutting would run smoothly. After small adjustments on the 3D design, we set forward in making our robot.

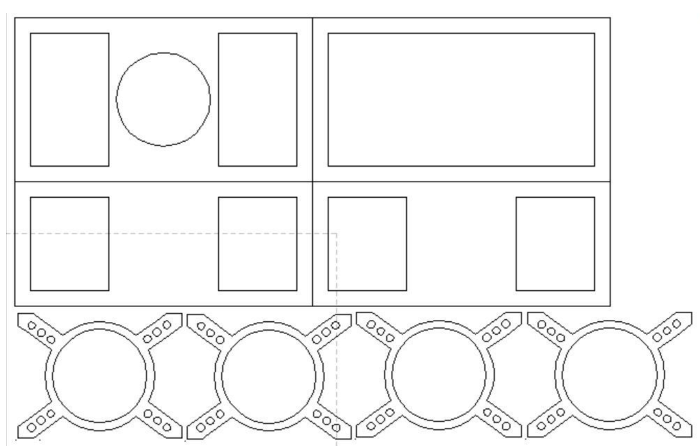
The images on the left and right illustrate our final design idea. The exploded view allows for visualisation of how each component of the robot comes together to form this year's iteration of the ROV. The drawings also specify the components' distances from each other, ensuring accuracy and precision when manufacturing the robot.





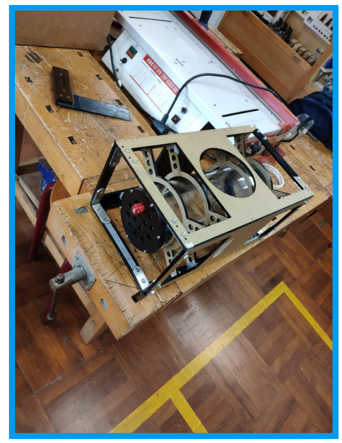
Finalised CAD model *Exploded view of model* *Isometric Design Blueprint*

To turn our 3D design into reality, we used 2D design software by TechSoft, also available through our school's student license.



2D Design of ROV external panels for use in laser cutter

By using various shape tools including the rectangle and ellipse tool, and tools from Adobe Illustrator to draw more complex shapes like the supports for the tube, we were able to replicate our design on this software. A laser cutter was used to cut the required pieces of acrylic. We used the dimensions from the CAD model to ensure it matched with our final design idea.



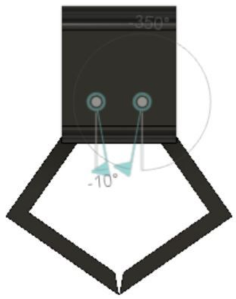
Production process: Frame assembly based on CAD model

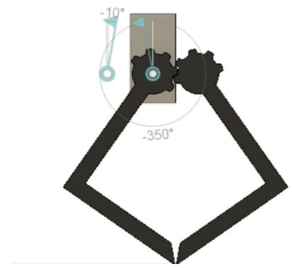
Propulsion

WHAL-E is propelled by T100 motors from Blue Robotics. Last year's robot, *Corion*, encountered difficulties in moving vertically, as with only a single motor aligned along the vertical axis it was difficult to overcome any slight deviations from neutral buoyancy. To fix this, we decided that purchasing a fourth T100 motor would be a worthwhile financial investment.

The thrusters are stopped by a PWM signal of 1500 microseconds. The T100 thrusters operate with values of 1100 to 1900 microseconds, with their speed and thrust increasing as the value strays farther away from the signal deadband of +/- 25 microseconds, centered around 1500 microseconds. The signals are all 5V, produced using PWM digital output pins on the Arduino Uno microcontroller.

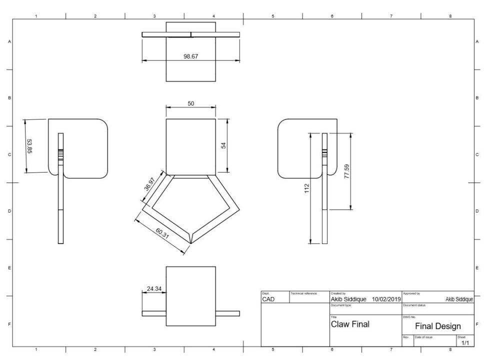
Claw





Claw Vertical View with Housing *Claw Interior view*

The claw was designed to ensure safe and effective use. The claw and the housing are designed to be made out of acrylic to suit with the rest of the robot frame.
The claw is attached to a servo by pegs and a screw. As the servo is switched on, information from the computer will cause the servo to rotate the peg which will open up and close the claw handles. The design requires two pieces of acrylic to be bent by 80 degrees for the handles of the claw. This was later done with use of the the acrylic bender.



Isometric Drawing of Claw and Housing

The design of the housing of the claw was manually made with 5mm acrylic. This ensures that all the electronic parts can be protected from water damage.

Sensors

In order to develop a robot capable of gathering information from its surrounding environment, we implemented a dual-camera setup into our robot. To prevent issues with exposing sensitive electronics to water, we decided to source our cameras from an endoscope camera manufacturer, which specialises in dealing with submerged or otherwise water-filled environments. By using two cameras, we ensured proper depth-of-field sensing as well as allowing for backups in case of equipment failure. The cameras are connected via ethernet cable to the external control platform, which allows them to send data efficiently with minimal equipment footprint. Finally, the temperature sensor connects directly to the arduino and sends data with each temperature value every given interval, which then sends the data to the Raspberry Pi.

Buoyancy

A critical necessity to *WALL-E's* functioning was achieving neutral buoyancy, as it would allow motors to propel the robot to their full capacity in any direction. Acrylic was used for the entire frame of the robot, and the density of the specific acrylic we used was measured at around 1070kg/m³ (for reference, the density of water is closely approximated by 1000kg/m³). In contrast, the alternative of PVC would have weighed around 1400kg/m³. This design choice not only allowed our robot to be organically closer to neutral buoyancy, but allowed achieving perfect neutral buoyancy to be done more easily - once our watertight enclosure was filled with air, *WALL-E* was positively buoyant, meaning that we had to simply add weights rather than cumbersome floats. Naturally, the impurity of water and a litany of other factors call into doubt our theoretical considerations - however, a real-life water test confirmed that *WALL-E* is indeed neutrally buoyant to a good approximation.

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

Archimedes Buoyancy Equation

Electronics

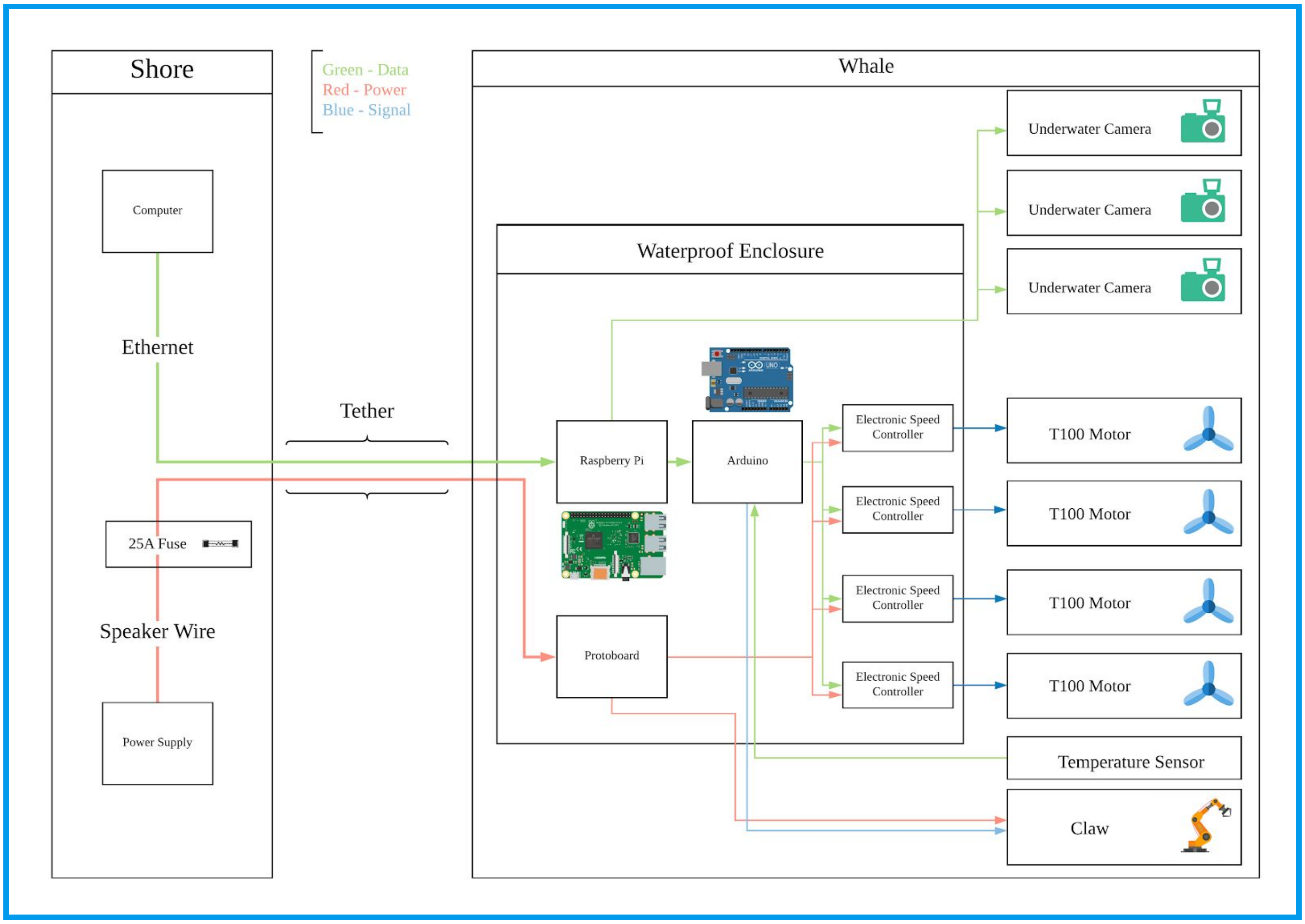
Electronics Summary			
Item	Current (A)	Quantity	Total (A)
Thrusters	5.0	4 (3 max at once)	15.0
Camera	0.060	3	0.18
Arduino	0.54	1	0.54
LED	0.20	1	0.20
Motor Controllers	0.050	3	0.150
Raspberry Pi	0.18	1	0.18
Servo Motor	1.0	3	3.00
Average Draw	-	-	19.3
Worst Case Draw (120%)			23.1

In order to get the right fuse size, we had to calculate the total draw of the robot, as can be seen above. In reality, the ROV will be only running 2 or 3 motors at once, resulting in a true max current draw of ~19A. This power supply is supplied from the protoboard on which the rails are set and there is a voltage regulator for the servo (which only runs at 5-7 volts). However, from the calculations, it is evident that the use of a 20A fuse would result in the fuse popping under slight deviations from “normal” loads. Once again, none of the motors would be running at 100% because that could damage the motors and heat up the protoboard if set to 100% for long periods of time. This would be counterproductive so we mostly run the motors at 80% of full throttle. This is done by varying the signals sent to the ESC. To conclude, the fuse was set to **25 Amps** because we assume a worst case scenario in which the motors are at 100% and 3 are running with all other components of the robot running multiplied by 130% (~24.9 Amps) to ensure the robot does not blow the fuse under slight fluctuations of current.

The Arduino Uno is the main controller unit for the electronics (connecting to both the T100 ESCs and servos). However, data transmission to the Arduino is routed through a

Raspberry Pi. In addition, all the cameras are directly connected to the Raspberry Pi. While connecting everything to the Raspberry Pi may seem more complex at first, in reality, we actually found it a significant benefit as we simply need a single cable to transmit all the data.

The following is our system interconnections diagram:



Application of Design to Mission Specifics

Due to time constraints, we weren't able to implement full solutions to missions, hence we focused on relatively basic tasks.

For the dam’s inspection and repair, we focused on inspecting the foundations of the dam and inspecting and replacing the trash rack. This would require a camera attached to the ROV, a way of measuring distance underwater, and a claw. The camera we bought was already waterproof, and can be connected to the Raspberry pi. We then decided on using lasers for measurement underwater, where through the known distance between the lasers and the angle of the lasers from being parallel, we are able to effectively calculate distances underwater. The claw that would hold on to the trash rack would be required to hold on to a U bolt, hence the design of the claw was based around this. The trash rack would be placed at an angle, which would require some sort of supporting mechanism that would allow for the angling of the trash rack.

To maintain healthy waterways, we would monitor the water quality, determine the habitat diversity, record the date, time, temperature, pH, phosphate, and species diversity on a data sheet, and restore the fish habitat. To achieve the water monitoring, we would need to have a water collection system. We used a water container with a lid for this task. We will then use the sample of water collected to measure the pH and phosphate levels of the water sample. To lift the rock from the bottom, we decided upon using the same claw for the trash rack for the rocks. Examining species underneath the rock would be done through our camera. Image recognition would be used in software to determine the species and amount of it underneath the rock. To restore the fish habitat, the degraded rubber tire and the installation of a new reef ball would be completed by the claw.

For preserving history, we would determine the lift capability of our ROV before the competition, then at the competition we will calculate the amount of force needed to lift the cannon. This would be done by calculating the volume of the canon through our laser used for determining the length of the cracks in the first task, then determining the composition of the cannon through the cannon’s casting mark, which would be done through the camera. Then, using our prior calculations we will be able to determine if our ROV can lift the cannon. Then we will use the claw to attach to the cannon to lift it to the surface of the pool. For the task of identifying and marking the location of metal cannon shells or non-metal debris, we will use the camera to identify, and software to determine the locations.

Materials and Finances

As a company, our access to various resources and materials was considerably restricted due to having limited sources of income. As a result of this, *Drowners LLC* strived to be as economically efficient as possible. For example, we attempted to reuse, refurbish and incorporate as many parts as possible from previous design iterations. At not only a substantial benefit in terms of environmental considerations, this method of lowering our production costs allowed us to have more liberty when purchasing essential components for the robot's design.

Not only are three costly and highly technically demanding brushless motors reused from *WHAL-E*'s predecessor, *Corion*, but all of the acrylic panels can also be taken apart and replaced to prevent unnecessary waste, showcasing our devotion to a sustainable future (once again mirroring with *WALL-E*, who, in his job as a trash compactor, painstakingly toiled to clean up the Earth).

Build vs Buy, Reuse vs New

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	Built/Bought	Reused/New
Motors	Bought	3 Reused, 1 New
Enclosure	Bought	New
Frame	Built	Reused
Clamp	Built	New
Electronics (wires,boards,Arduino,etc)	Bought	New
Control Box	Built	New

Camera	Bought	Reused

Important Budget Decisions

During the designing and building process, we were forced to make several major decisions which would impact the performance of our robot based on the limited budget available to us.

For example, when acquiring a camera for *WHAL-E*, we had to adhere to several strict guiding factors in determining what kind of camera to purchase. Not only did the camera have the ability to be adept and functional in high enough quality to suit our purposes, it also had to be able to be relatively economically accessible so that we would not be compromising the quality of our other purchased components. We settled on two options: either purchase a normal camera and waterproof it ourselves using epoxy, or just outright purchasing a waterproof camera. After much deliberation and many calculations, we opted for the latter option, as it was determined that this would both produce higher quality images with less risk of damaging the camera ourselves, as well as overall be less financially strenuous.

We were also faced with the decision of what material to construct the frame of the robot out of. Several options were available to us, including 3D printing the frame, aluminium, and CNC acrylic. 3D printing was more or less immediately ruled out as an option due to it being too expensive. Although aluminium is a sturdy and reliable material, it is also too heavy and overall did not outweigh the advantages gained by using acrylic instead, such as the acrylic neutral buoyancy and relative inexpensiveness, hence prompting us to finally decide on CNC acrylic.

Table of Expenses

Expenses			
Category	**Description**	**Quantity**	**Amount ($ HKD)**
Hardware (Blue Robotics)	T100 Motor	1	940.00

Hardware (Blue Robotics)	ESC	3	590.00
Hardware (Blue Robotics)	Watertight Enclosure (4" Acrylic)	1	1380.00
Hardware (Blue Robotics)	6mm Cable Penetrator	4	125.00
Hardware (Blue Robotics)	8mm Cable Penetrator	3	117.00
Hardware (Blue Robotics)	Blank Penetrator	1	30.00
Hardware (Blue Robotics)	T100 Nozzle	1	37.00
Hardware	Materials	1	315.00
Hardware	Acrylic	1	150.00
Hardware	Flares	1	150.00
Hardware	Cameras	3	470.00
Hardware	Servo	5	1240.00
Administration	Subscription Fee	1	3138.00
Hardware	Bullet Connector	1	95.00
Hardware	L-Brackets	16	80.00
Hardware	Protoboards	2	14.00
Total Budget:			10000.00
Total Expenses:			8871.00

Sources of Funding

This year, our school was able to provide us with a much more reasonable amount of funding compared to last year. Even though, we still had to reuse certain parts from our previous iterations, nevertheless, we maximised our resources and school facilities in order to produce the best possible robot.

Occasionally, our team members had to visit a range of stores to identify the hardware we needed at the best 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. To stay within this range we made sure to always keep our expenditure at a minimum and only purchase what was absolutely necessary.

Despite working under a lower budget than most teams, *Drowners LLC* achieved a budget surplus. We aim to use this surplus to get a head start on sourcing material for next year.

Safety and Testing

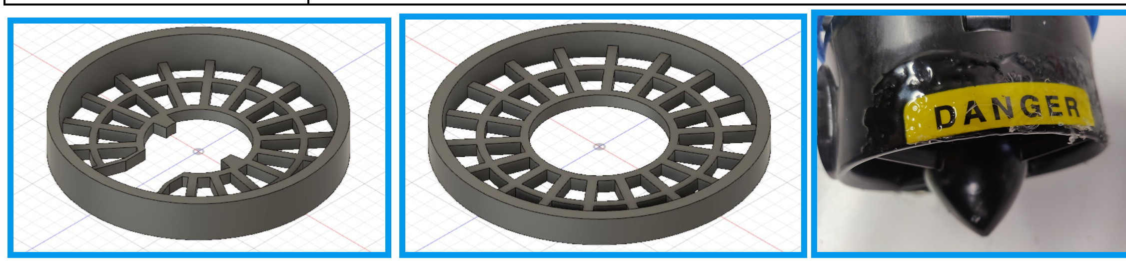
General Safety

Safety was *Drowners LLC*'s top priority. Every member is required to wear basic safety equipment (e.g. aprons and goggles) when power tools are utilized, such as when drilling or soldering. Loose clothing is secured and the surrounding working area must be clean to prevent tripping and fire accidents. The Chief Safety Inspector enforced the safety procedures and was satisfied with the team's conformity to them.

Safety Features

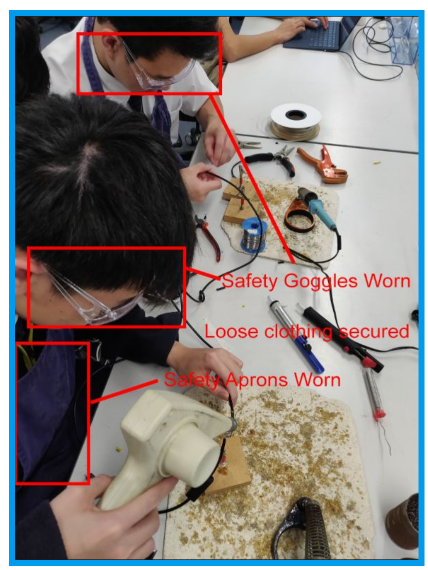
Safety Features	**Description**
Thruster Shrouds and Guards	Guards were design on Autodesk Fusion 360 and 3D printed and attached to the thrusters, preventing fingers or aquatic creatures from reaching the propellers and being cut.
Rounded edges	All the sharp edges were rounded off by using files to prevent injuries when touching corners.

Hazard Labels	Hazardous areas were taped with labels to ensure users will be aware of any possible injury prone areas of the robot. This prevents injuries..
Notification LEDs	Notification LEDs light up to show which modules are powered. This will also make the ROV more noticeable.Therefore, people will be aware of the robot underwater which will reduce the risk of accidents and collisions.
Fuse	Fuses are placed to ensure the circuit is kept safeguarded if too much current flows through. The fuses will break the circuit when the current exceeds that of the designated limit (25A), preventing electric shocks.



Motor Safety Features: 3D-Printed Shrouds and Hazard Warnings

Testing Protocols



Once *WHAL-E* was constructed, several testing protocols were conducted to ensure functionality and safety. First, a dry run was conducted to ensure all parts, except the motors, were functioning properly. The servos and the camera were tested and all were in working order. Due to the fact that the motors are water-lubricated, the motors could not be tested on land so the motors were individually tested underwater. All motors performed in response to the controls from the control interface. Next, the camera was tested underwater to identify any problems, of which there were none. After, the claw was tested underwater to check its functionality. It was able to respond to the control with a high degree of precision. In addition, we tested the claw by making it grab objects with low friction coefficients. The claw was able to perform the task. Throughout this preliminary testing stage, all members adhered to testing protocols. All members were not to touch any electronic parts unless they were idle. This was to prevent injuries from occurring. In addition, a member was stationed at the power supply, in case of any emergency.

Testing the ROV in Water

After the preliminary stage, we tested insulation of our watertight enclosure underwater. First, all electronics were removed from the watertight enclosure and replaced with blank material that mimicked the weight of the electronics. Resurfacing and inspection determined that were no leaks into the casing, bolstering our confidence in *WHAL-E*'s electrical safety. Next, the electronics were replaced for a final test of maneuverability and speed. The performance of *WHAL-E* was satisfactory in both of these aspects. The claw's ability to transport object to the surface was also assessed.

Overall, after the testing protocols, *Drowners LLC* feels confident in affirming that *WHAL-E* will be able to operate while meeting the stringent safety requirements imposed by both MATE and ourselves.

Testing Checklist

In order to facilitate a safe and efficient working environment, we devised a checklist which would provide for most existing safety concerns, as well as ensure that technical specialists and professional oversight were present for all production sessions involving heavy machinery.

In the workshop:

- ❏ Apron must be worn
- ❏ Safety Goggles must be worn when working with power tools
- ❏ Surrounding area is clear (e.g. other people at least 1.5 meters away) before working
- ❏ Workshop is tidy before leaving
- ❏ Member of Design & Technology Staff available to supervise

Before submerging into water:

- ❏ No leaks or signs of damage (e.g. cracks)
- ❏ Ensure fuse is correctly in place
- ❏ Tethers are organised
- ❏ No hazardous wires
- ❏ Joints are tight and secure

Before powering on electronics:

- ❏ Confirm the correct polarity of components connected to mains supply
- ❏ Ensure fuse is placed correctly
- ❏ Check for detectable visual problems with circuitry and wiring

Time Management

During our initial sessions, we worked on creating an efficient timetable which allowed us to develop a highly complicated design within a limited timeframe, along with planning for specialised designs in order to complete the tasks set out in the proposal. This allowed us to coordinate our team efforts and better realise our conceptual vision.

The primary subtasks we identified included:

- Deciding on material type
- CAD design
- Coming up with a parts list
- Buying the parts
- Building the frame
- Installing electronics
- Programming
- Testing and adjustments

The team was very efficient when it came to timing, working in just 3 months to complete the designing and building of parts. To make sure the limited time we had was being used as efficiently and diligently as possible, we established multiple meetings per week to coordinate different divisions including the design, production, and technical teams, as well as developing a plan for the construction of the separate portions of the ROV. A detailed developmental Gantt chart can be found on the next page:

Development Time Frame Gantt Chart

Note: Each Box is 2 weeks

Tasks	18/11 - 01/12	02/12 - 15/12	16/12 - 29/12	30/12 - 12/01	13/01 - 26/01	27/01 - 09/02	10/02 - 23/02	24/02 - 23/02	10/3 - 23/03	24/03-07/04	07/04 - 20/4
Deciding on material type											
CAD design											
Coming up with parts list											
Buying the parts											
Building the frame											
Installing electronics											
Programming											
Final testing and adjustments											

Below are detailed breakdowns of the various subtasks:

Deciding on material type:

- Before we could begin and design the robot, we needed to know which material the chassis of the robot would be made of. Different materials have different limitation, so we were tasked with researching all the possible materials and decide on it by the end of the first week.

- We decided to use acrylic as it was the perfect blend of economic and versatility.

CAD Design:

- We then needed the CAD team to come up with how the robot would look like. They used Fusion 360 and had four weeks to design the robot.
- This task overlapped with buying the parts, as we started shopping for essential parts early to ensure we had enough time.

Parts List and shopping:

- We had four weeks to decide what parts we needed. This meant that at the end of the four weeks, we were sure what parts to buy and how to continue
- We allocated a lot of time to shopping, as we knew it would be had to obtain some of the parts, and the parts bought online from blue robotics would take a few weeks to ship.

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:

- Using Fusion 360 to draw and model the exterior casing structure and support structures for laser cutting.
- 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
- Drilling holes and using L connectors to hold the acrylic together
- Add on support structures that will hold the casing and main structure

Assembly:

- Add the electronics 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

If we were to participate in this competition again, there would be multiple improvements we could make. The first of these improvements would be to stick to our schedule more tightly, because some of the earlier sections were delayed slightly, such as difficulties in purchasing resources, which caused a domino effect and made events later on harder to complete on time. Overall though, we stuck to the schedule reasonably well and were able to complete the robot efficiently with ample time to test and adjust.

Challenges, Takeaways and Future Improvements

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 we 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.

Future Improvements

Vijay: *"We were given heavy time constraints due to our academic pressure, despite being occupied with our IB lives we still managed to get the job done and produce a functioning robot that met all our targets. There was effort from everyone throughout the process of creation, while the endeavour is still not over, I believe that no matter what results we produce at the competition it was still an extremely worthwhile learning experience. "*

Jayesh: *"Despite our heavily restricted monetary funds we still managed to purchase all the required machinery and produced a good final product. We had to go through many stages of planning, organizing and research to make sure we were getting the most cost-value machinery so that we could afford to buy all we needed with our small budget."*

Junyi: *"I was tasked with creating the blueprints of the robot. Having little experience within the field of robotics it had to conduct a lot of research and ask last years senior designer for advice and help to successfully complete my project. I believe that no matter what our final placement is in the competition it was all worth-while and an experience that I would definitely recommend to other people interested in robotics."*

Gaurav: *"The process of creating the ROV was a tedious and difficult process that required us to devote a lot of time into it, however the teams incredible efficiency and restlessness helped us pull through, task after task, solution after solution. We always managed to handle difficulties in both the 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 one we had to decide which were important and which we could afford to lose. This experience has not only helped me become more knowledgeable within the field of robotics, I have also built strong bonds with many new people that I have met throughout the process. I have developed my ability to communicate, co-operate and organize myself through these past few months of design and production. Despite the pressure load from my academics I will be sure to come back next year and participate again."*

Ismet: *We learnt a lot from our past experience from last year and didn't make any similar mistakes as to the year before. This year, however, we had huge troubles with the buoyancy testing of the robot. Through countless trials and errors, and brainstorming on which component was causing the buoyancy issues and came up with various methods to tackle the issue.*

Daniel: *Time management was a huge issue for the team last year, this year we learnt from our mistakes and scheduled weekly sessions that were "compulsory" so we managed to get everything done 2 weeks in advance, this gave us a lot more time to do* *final improvements as well as testing and slight modifications to our observations. One of the major issues with the design of our robot was being able to fit everything into the "cage". For this specific project we decided to take a bottom-up approach which meant that we designed each specific component and then found a way to piece them together and fit them into a cage which turned out to be quite stressful and complicated, instead we should've done the opposite, a Top-Down approach where we design according to the final cage design that we would have to fit all the components in and work our way down to each specific component according to the dimensions of the cage.*

Balancing Multiple Commitments

One challenge shared by all members of this year's underwater robotics team was dealing with the overwhelming pressure of GCSE and IB courses and examinations, while still making steady progress on the robot. To achieve this, we devised a regular rotation for people attending the after school sessions so that everyone could contribute without having to go every day. Moreover, we assigned people into various groups which followed parallel rotation schedules, and as each group performed a different task this ensured coherency between sessions despite varying personnel.

	Week 1	Week 2
Monday	Group 1	Group 1
Tuesday	Group 2	Group 3
Wednesday	Group 3	Group 4
Thursday	No session	All Available
Friday	Group 4	Group 2

Drowners LLC's bi-weekly schedule

Future Plans

In order to continue our strategy of eco-friendly design, we plan to reuse most of our heavy electronic equipment in future prototypes to prevent needless waste. Furthermore, in order to develop a sustainable innovation strategy, *Drowners LLC* involved many junior members in our production team this year, which will hopefully transform into a sustainable legacy after many of the main executive team graduate next year.

Team Members

Vijay Sambamurthy (Chief Executive Officer)
Gaurav Arya (Chief Electrical Engineer)
Ismet Ozer (Chief Mechanical Engineer)
Chris Pang (Chief Information Officer)
Daniel Guo (Chief Safety Officer)
Akib Siddique (Chief Design Officer)
Shing Wai Pun (Electronics and Design Officer)
Alex Chak (Electronics and Safety Engineer)
Ethan Fong (Acrylic Specialist)
Wessley Ng (Acrylic Specialist)
Nikhail Wadhwani (Chief Financial Officer)
Jayesh Chatlani (Logistics Supplier)
Junyi Xie (Graphics Designer)
Elly Hung (Technical Writer and Electronics Engineer)
Adrian Chow (Technical Writer)
Chak Ming Tung (Safety Inspector and Frame Specialist)

References

https://www.bluerobotics.com/store/thrusters/t100-thruster/
https://hobbyking.com/en_us/power-hd-lw-20mg-servo.html
https://www.marinetech.org/
https://www.arduino.cc/
https://www.makerspaces.com/arduino-uno-tutorial-beginners/
https://www.khanacademy.org/science/physics/fluids/buoyant-force-and-archimedes-principle/a/buoyant-force-and-archimedes-principle-article
http://www.blog4safety.com/2017/02/safety-precautions-to-take-when-working-with-electronic-equipment/
https://www.ifixit.com/Wiki/Electronics_Water_Damage
https://www.makeuseof.com/tag/best-ways-protect-electronics-flooding/

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