ARC

GERMAN SWISS INTERNATIONAL SCHOOL

HONG KONG

Member	Role
Elliot Jinoo Hong	Chief Executive Officer, Software & Electrical Engineer, Designer, Pilot
Arushee Kadam	Mechanical & Electrical Engineer, Designer, Co-Pilot
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Jeffrey Chak	Software Engineer, Safety Officer, Onshore Crew Member
Cyrus Lam	Mechanical engineer, Tether Supervisor
Mr. John Shearman	Mentor

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Abstract

Arc was founded in November 2017 with the goal of creating an ROV capable of handling a variety of challenges both effectively and accurately. The team consists of five dedicated members, all with varied skills - some are experts in electrical engineering while others great at programming. Together, Arc has developed ROV NOAA.

Our company's main goal is to provide the best ROV that can adapt to the tasks at hand and to its environment. NOAA is aimed at taking on a wide variety of underwater tasks in a multitude of different conditions with ease. Within the ROV we have incorporated design elements that make this ROV more adaptable than traditional ROVs. Whether it is the small chassis and therefore nimble manoeuvrability, or the swappable tooling plate that allows for the easy installation of task specific tools, ARC is designed to be as adaptable, and yet also as specialized as possible.

Furthermore, it has been designed, created and tested by ARC with the aim of striking the perfect balance between the cheap prices of off-the-shelf components with the flexible capability of custom made ones. With recent rapid improvements to technology, we, ARC, believe that a ROV made for everyday consumers is becoming a possibility reality. Therefore, although this ROV is designed to be used commercially to help with the underwater operations needed by the University of Washington, we challenged ourselves to make the ROV as affordable as possible, in order showcase the future possibility of affordable, yet capable, ROVs for consumers. Of course, for prospective buyers and investors, such as the University of Washington, the lower costs are extremely beneficial.

Company Structure

At ARC we believe strongly in using our resources and capabilities to the fullest. Experienced, 'core' members of the company hold a permanent position (e.g. electrical engineering). Less experienced members are assigned different, temporary positions under the guidance of a core member, in order for them to acquire a vast variety of skills. There is no corporate hierarchy at ARC; instead, we believe in equal distribution of power throughout every team member, which allows for the integration of everyone's ideas. Short, daily meetings ensure that all members of the company contribute to the decision-making process. We strongly believe that this way of running the company provides every member with many colourful learning opportunities, while allowing for innovative ideas that may otherwise be deemed as 'crazy' to be implemented. This structure allows the company to reach its fullest potential.

Design Rationale

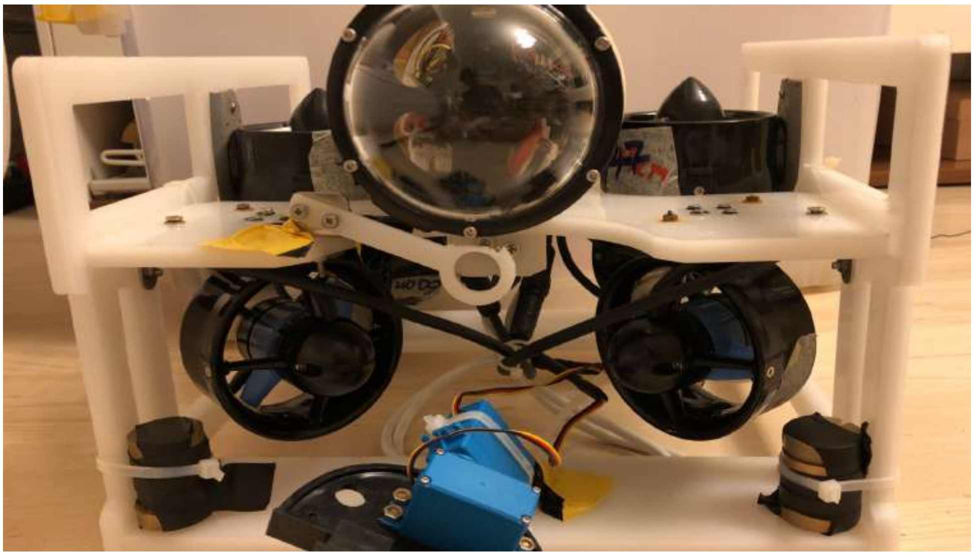
Chassis

While much has not changed from last year, the chassis was something we completely redesigned from the ground up. It was therefore the part of our ROV that required the most attempts to perfect. We had to design several different versions of the chassis to achieve the right size, weight, precision, and manoeuvrability.

Our first chassis attempts were very large and designed to make the mounting of the thrusters more efficient. Using this first chassis, we made measurements and scaled the size down to perfectly fit the needed thruster configuration.

The final chassis has two symmetrical side panels, with a middle panel to which the horizontal thrusters and the watertight compartment are fastened. At the bottom, towards the front of the chassis, is the tooling panel to which we attach our claw. Our chassis was laser cut from polypropylene plastic, at a thickness of 10mm. This material was chosen due to the similarity in density to water, therefore allowing us to correct buoyancy issues with minimal changes. The thickness also allowed for us to mount various tools and devices onto the chassis without the worry of putting too much strain at a point.

Fig 1. Front view of ROV



The chassis is designed to be almost perfectly symmetrical, making it balanced. Sections are cut out of the side panels to minimize the resistance of the chassis when it is in the water. This makes the ROV easy to manoeuvre.

The watertight compartment is fastened to the chassis using circular loops which attach to the middle panel. In a previous design we found that positioning the watertight compartment too high or too low resulted in the ROV tilting when we moved it forward; to combat this we ensured that the watertight compartment was perfectly in the centre of the ROV.

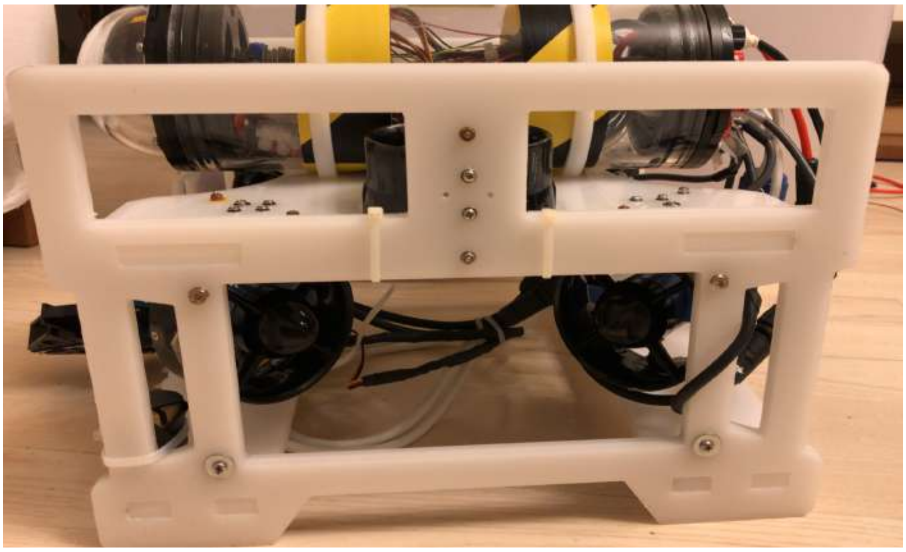


Fig 2. Side view of ROV

The highlight of the chassis is that the panels all fit into each other using tabs that fit into slots on the side panels. The chassis is then further secured together using L brackets and bolts. This ensures that it is held firmly together.

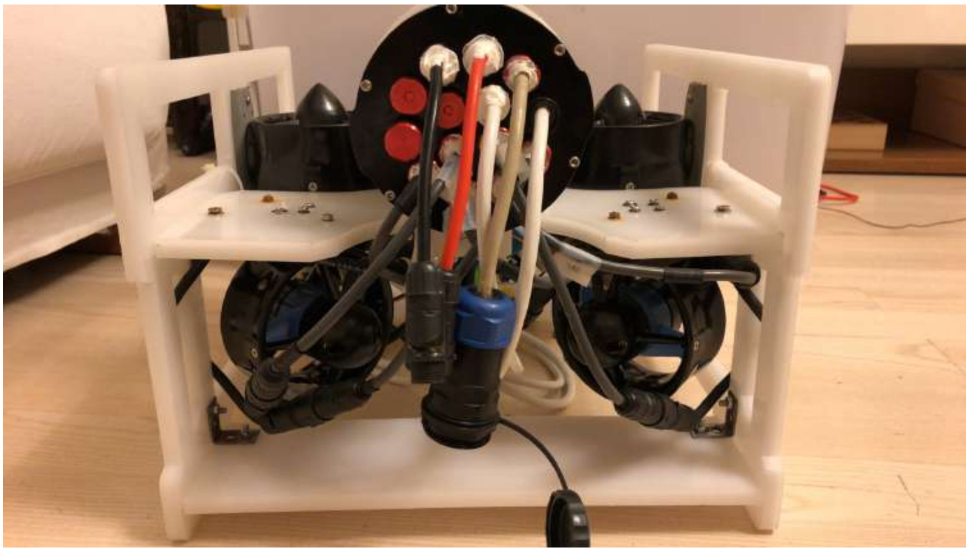


Fig 3. Back view of ROV

The compact design and lightweight materials allows for our ROV to weigh only 8.4 kg and with dimensions of 39cm x 33.5cm x 28.5cm. The chassis was developed using a CAD program, LibreCAD, before getting cut out using a CNC router.

Buoyancy

Due to the air-filled WTC, the ROV had initially been very positively buoyant. To counter this, we experimented with weights of 50 grams, aiming to achieve a perfectly stable configuration of weight distribution. Eventually, we discovered the best places on the ROV where simple weights could reverse the effects of unequal distribution of buoyancy.

Brass weights were used, due to the material's high density, and the fact that it is readily available at our disposal. Testing was done by hanging stacks of weights below chosen points on the chassis.

Fig 4. Stack of 5 50g weights

Fig 4 shows the final result of our buoyancy testing. We found that the front of the ROV is very heavier as compared to the back, possibly due to the tooling panel; thus the back required a larger number of weights to balance the ROV.

The final result was achieved by: 250g of weight on each side of the tooling panel at the front of the ROV and 50g of weight at the centre of the tooling panel.

Propulsion System

The choice of thrusters boiled down to two factors: reliability, and power. At first, our ROV was powered by simple, brushed DC motors- we used bilge pumps. However, this quickly proved to not only be inefficient, but also unreliable, and we had many technical issues with them.
Our team quickly found a better alternative- brushless DC motors. Due to the lack of a physical commutator, more electrical energy is preserved. There is also less chance for internal components to break, since a BLDC is powered by the on-off sequence of electromagnets, instead of the high friction commutators in a Brushed DC motor.

Fig 5. Blue Robotics thruster

We selected the Blue Robotics T100 thruster due to its reputation for being reliable. This thruster eliminates most possibilities of error. Not only does it have plastic bearings in place of metal ones- which can rust and fail, it also comes with a robust exterior that suits our uses, working normally even under the most extreme conditions.

Configuration

We could afford eight blue robotics thrusters with our budget. Under this restriction, we decided to use four for horizontal motion, and two for vertical motion, with two left for spares in case of failure or other causes for replacement.

Our horizontal thrusters are positioned in a rather creative way to allow maximum flexibility of manoeuvring. The four thrusters are fastened to the middle panel in a square, each thruster positioned diagonally.

This allows us to not only move forwards and backwards, but to also pan sideways, resulting in the ROV's motion being far more flexible and hence allowing us to complete tasks faster.

FIG 6. VIEW OF ALL THRUSTERS FROM THE BOTTOM OF ROV

Our vertical thrusters are positioned towards the top of the chassis, fastened to the middle of the side panels.

This allows us to move up and down while maintaining the balance of the ROV, allowing for more stable manoeuvring, which is critical in performing complex tasks. It also balances the weight of the ROV, adding to its stability.

Watertight Compartment

Being an incredibly vital part of our ROV, as electronics and control systems were stored within this waterproof container, we sought out to design this part of our ROV first. Due to our desires of better manoeuvrability, we decided to use a WTC because it allowed the tether to become much thinner and lighter, as we can power everything by sharing ground and power. Since the tether was more flexible, our ROV could be maneuvered far more easily.

We originally arranged for an acrylic tube and ring to be manufactured and combined, in order to store our electric connections. The original tube was sturdy and to be “trusted”, but the ring was not. There were numerous weak points in the plastic of the ring that allowed it to be easily damaged and water to easily flow in, which is the main reason why a WTC was needed for building a ROV. Furthermore, when we tried to screw the ring to the tube for maximum protection, the plastic walls of the tube constantly cracked and broke, which was, at that time, a design flaw that we overlooked.

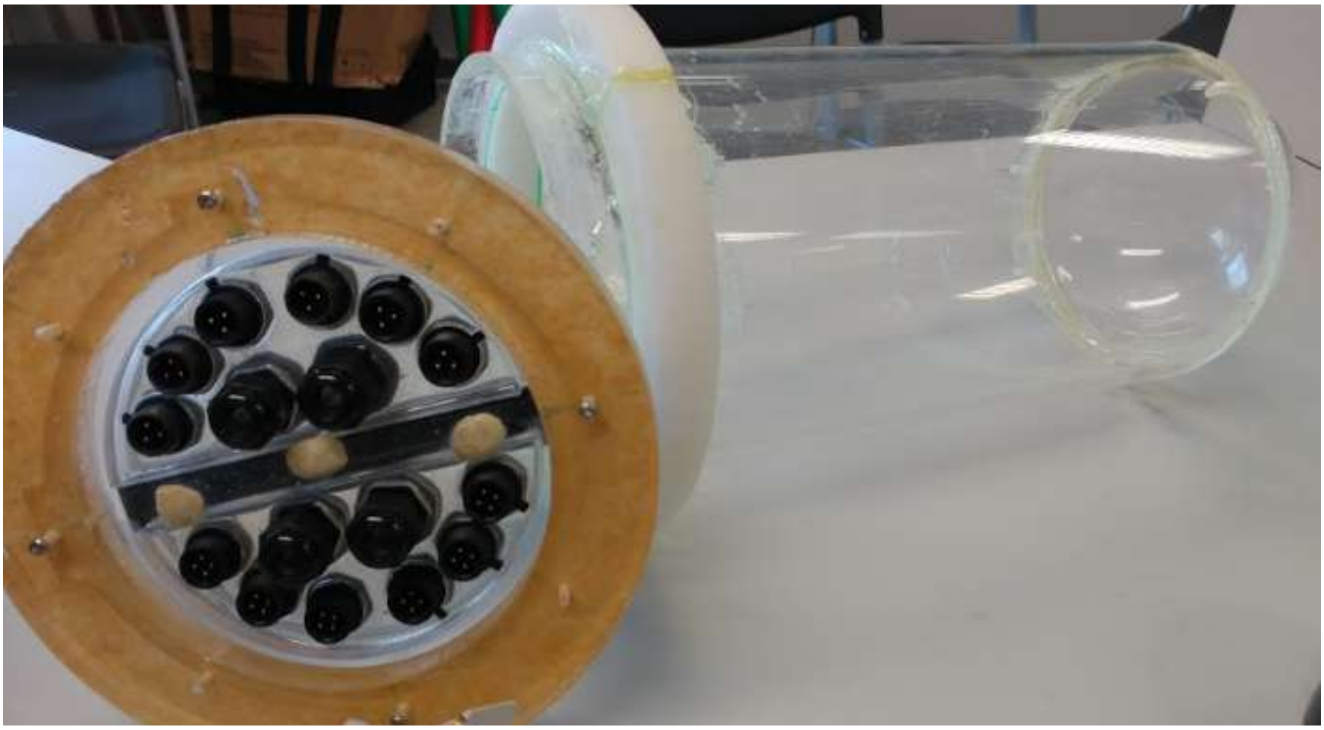


Fig 7. The first, faulty WTC

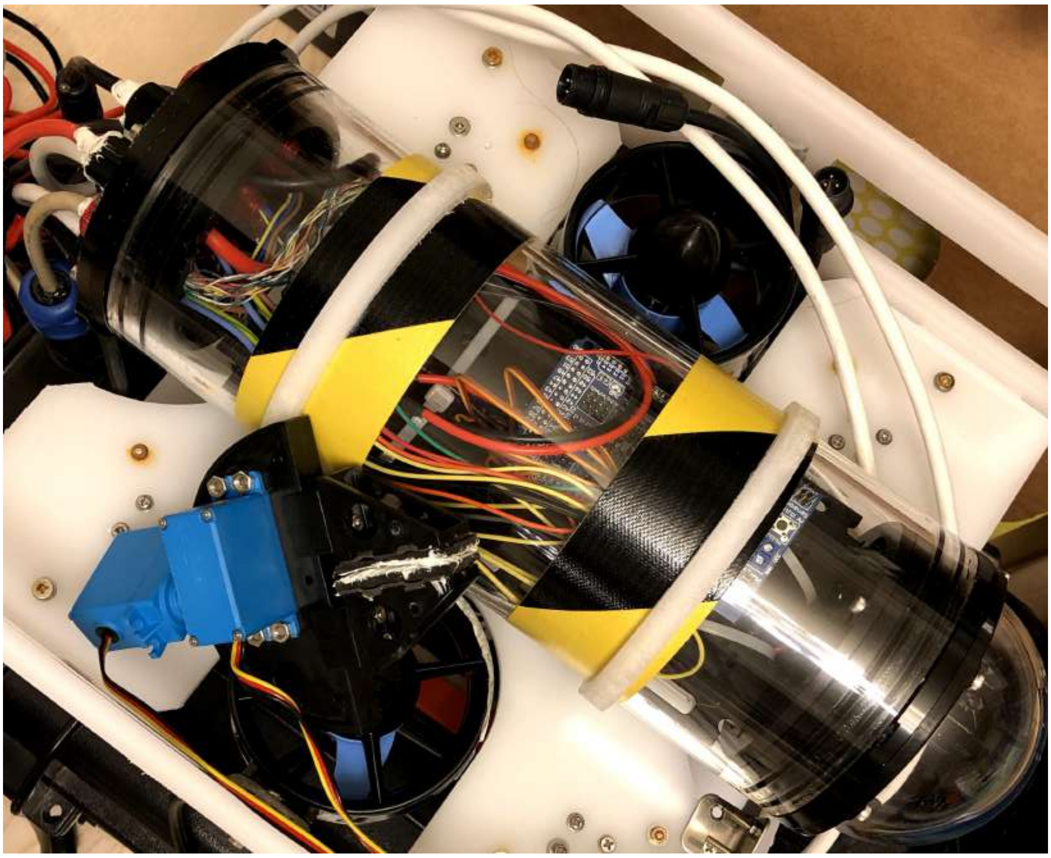


Fig 8. Blue Robotics WTC

Lacking in time and in funds, as manufacturing a new tube with new dimensions and new material was high in cost, we bought a WTC from Blue Robotics and assembled it at an alarmingly fast rate. The WTC was expensive in its own right, but was a safer choice than manufacturing a new plastic tube and realising that it did not do a much better job than the previous one.

Our current WTC has 21 O-rings to make the entire compartment waterproof, including the ones in our waterproof connectors. Not only is it safely waterproof, it also has an enclosure vent that can neutralise internal air pressure when lid is pressed in.

By scrapping our original plan of an original WTC, we decreased the uncertainties and doubts about the WTC and can safely assume that our WTC will not be letting water into the most vulnerable part of our ROV.

Camera

The camera is one of the most important components of the ROV; hence ARC expended large amounts of effort into making our cameras work in time for the competition. In order to choose which type of camera was the most suitable for our mission objectives, we drafted a table showing the pros and cons of two options that we had narrowed down from a larger list. The two options were either a conventional 'waterproof' parking camera, or a fishing camera that is supposed to be attached near a hook of a fishing rod.

After hours of testing and discussion, we finally chose the fishing camera as our main camera for our ROV, as we believe that the advantages of using the fishing camera significantly outweighed the disadvantages (especially the cost). Furthermore, the unreliable waterproofing of the parking camera was a huge concern, as we wanted our video feed to readily be available.

To supplement the main camera, 5 more fishing cameras were also used on other parts of the ROV. These were attached at the following positions:

- Towards the front, facing the tooling panel
- At the bottom
- Left
- Right
- Tooling

The video-processing centre of the ROV features 6 screens that came with the fishing cameras to allow the pilot to be able to monitor all camera feeds simultaneously.

Fig 9. Parking camera

Fig 10. Fishing Camera

Parking Camera Pros	Parking Camera Cons
The cameras were very cheap (Under US$15). This allowed us to buy a couple cameras without using up a large portion of our budget. Versatile, as the cameras had AV output cables allowing us to connect them to different monitors of various sizes. Input power to the camera is 12V, so there was no change in voltage needed.	Video output is mirrored, which can cause confusion when turning left or right. The integrity of the camera waterproofing was a major concern, as some cameras showed signs of water damage after testing. The connections had to be waterproofed with waterproof tape and epoxy. A long, bulky tether had to be used to connect the power to the camera.

Fishing Camera Pros	Fishing Camera Cons
Waterproof and durable. The camera was built for underwater use, therefore it can be trusted for use during missions. The camera is connected by a long 25m strong thin tether which can endure 15kg of tension force (according to the supplier). The camera has a wide 160-degree field of vision. The compatible camera, tether and monitor are compact and can fit in a small box. Uses UV light to illuminate image • Good for minimizing impact of blinding lights on aquatic life.	The price of one fishing camera including its components was significantly higher than the cost of purchasing a parking camera, tether and monitor. The fishing camera had a 2.5mm jack video output, making it compatible only with the small monitor that came with the camera. The input voltage of the monitor and camera was 7.4 Volts, therefore the power supplied to the camera had to be stepped down from the original 12 Volts.

Tether

The tether is an extremely important component of our ROV, serving as the bridge between our actual submersible and our above land control station. Consisting of several wires, each relay different outputs, we had to take a certain amount of care in making this part in order to ensure that our ROV received the correct inputs that would allow it to function properly. We used a thick red cable to transfer 12V of power to our ROV in order to power it, making sure the resistance was minimal, while a thick black cable was used as ground. Additionally, we had an Ethernet cable, which we used to send all electronic signals that instructed the ROV on how to move and which tools to use. This cable came with 14 internal wires, surrounded by a metal shield and rubber insulation, but we only needed to use 12 for the signals. These smaller wires were plugged into the Arduino board, which then further relayed them to the thrusters and tools. Additionally, we had to have 6 further wires for our 6 fishing cameras.

FIG 11. SHEATHED TETHER + FLOTATION DEVICE

However, in order to bundle the cables together, we had to think outside the box. It was important to get them in somewhat of a single tether, as this would prevent the wires snagging on anything or getting caught in the thrusters. For this purpose, we have a mesh sheath that encloses the power, ground, signal, and camera wires. The mesh had the advantage of not only gathering the wires together to minimise their resistance in the water to ensure easy manoeuvring of the ROV, but it also provided some protection for the wires, ensuring that they would not be damaged by any sharp edges they encountered in their environment. We also attached pool noodles at regular intervals along the tether to make it somewhat buoyant so that it would not drag along the floor of the pool and impede the motion of the ROV.

One upgrade from last year was making the tether detachable from the ROV. This makes the ROV far easier to handle when transporting. It also makes the process of disassembly for upgrades or debugging far easier. Furthermore, this allows us to implement a modular aspect to the ROV - if one component fails, it can be disconnected and replaced quickly.

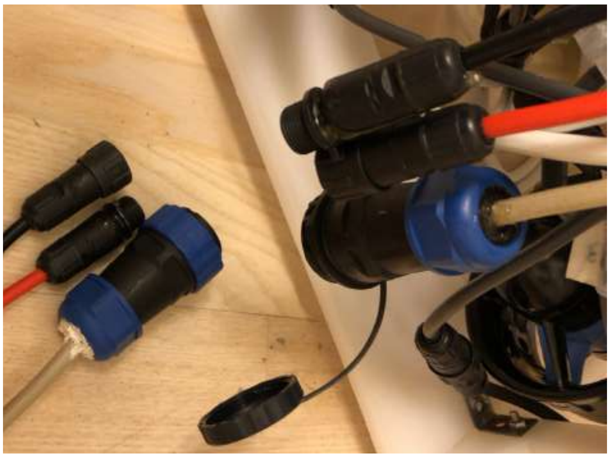


FIG 12. DETACHABLE TETHER CONNECTIONS

Control System

Hardware

Aware of how delicate control system components, joysticks and Arduinos, can be, we decided to modify a large pelican case. The pelican case, made of thick durable plastic, allows the control box to be transported without the risk of damaging electrical components. Furthermore, the pelican case is lined with Velcro, allowing for components to be easily taken out and replaced without damaging other components - a possible risk when using a screwdriver near a microprocessor.

At the heart of the control system is an Arduino Mega 2560. With 54 input/output pins, 16 analogue pins, compatibility with a plethora of accessories, sensors and components and a vast library of in depth documentation of its programming language, the controller enables the ROV to be as flexible as possible. Furthermore, it is relatively cheap, and in our testing, provided superior motor control compared to the Raspberry Pi - this however could have been due to our poor program optimisation on the Raspberry Pi.

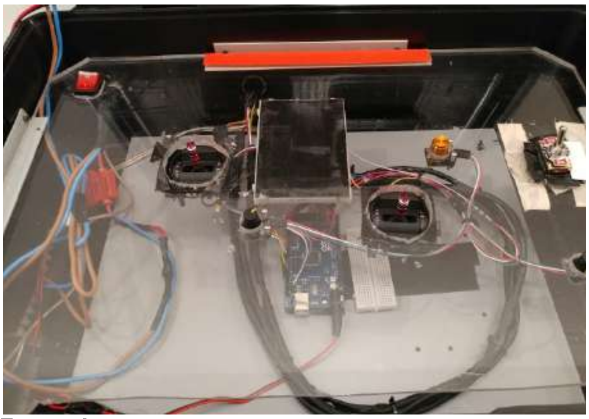


Fig 13. Inner workings of the control system

Fig 14. Outside view of pelican case

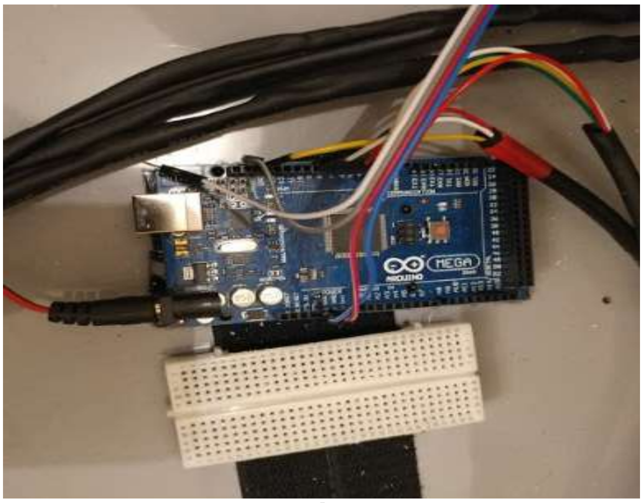


Fig 15. Arduino MEGA 2560 → centre of the control system

Controls

We decided to use separate joysticks and dial potentiometers instead of a ready-made controller such as an Xbox controller because it allowed us to be more flexible and tailor the controls specifically to the ROV. Instead of being restricted to certain joysticks and buttons, we were able to design our own control layout.

Fig 16. ROV Controls

The layout is intuitive – the left side is dedicated to vertical thruster control, the right is for horizontal movement and the very right, where the co-pilot will be sitting, is for tooling. This layout is optimised so that the pilot has the best driving experience possible, as their left hand does not ever need to cross over to the right hand side and vice versa.

Although somewhat expensive, we decided to opt for big joysticks as they allow for more precision in comparison to thumb sticks.

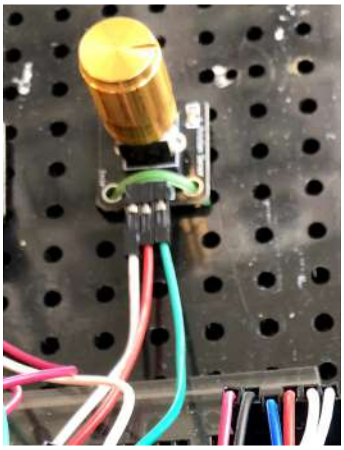


Fig 17. Dial Potentiometer

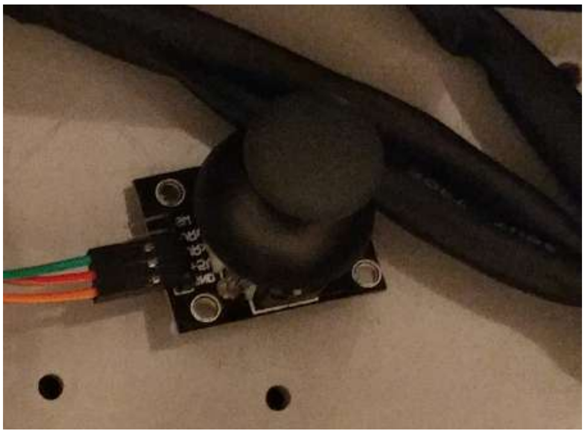
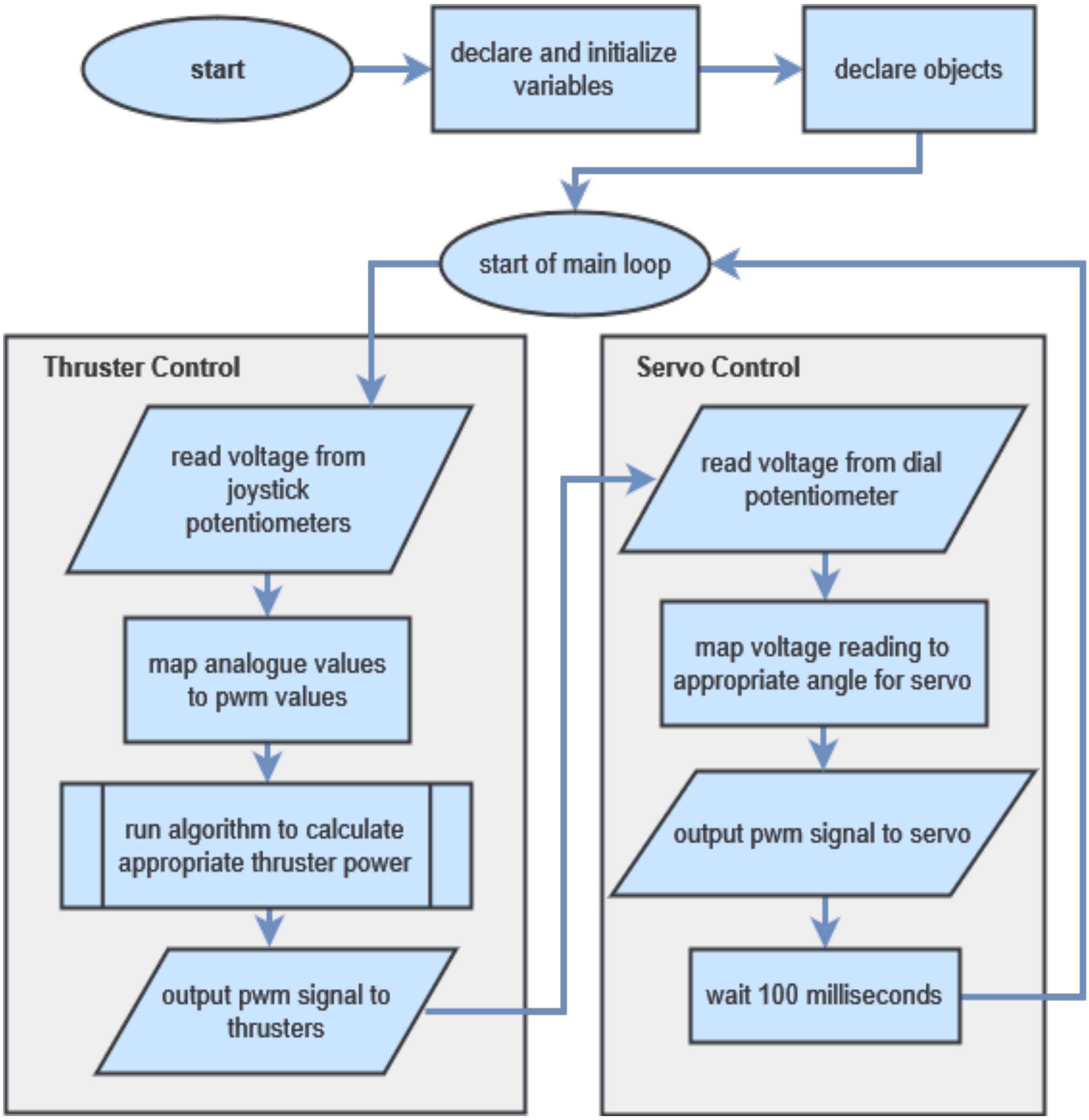
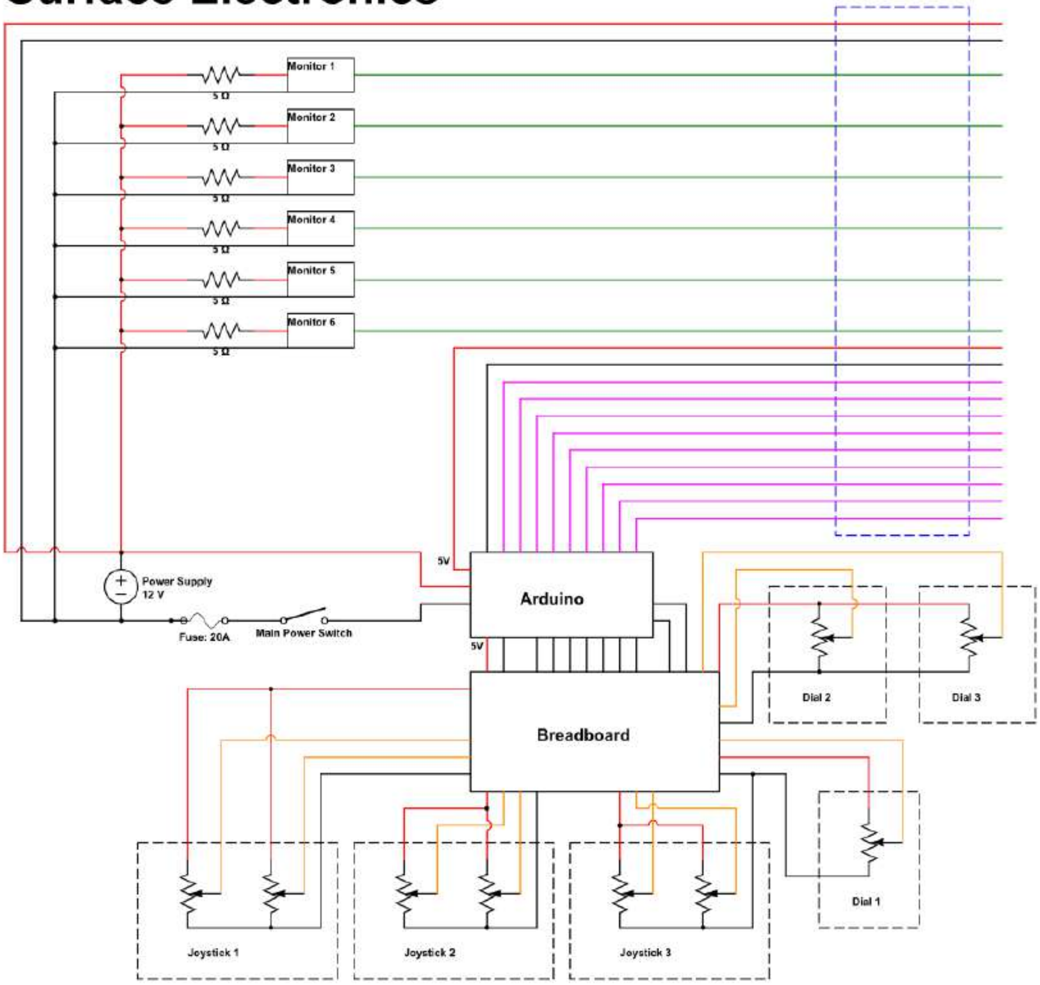


Fig 18. Joystick

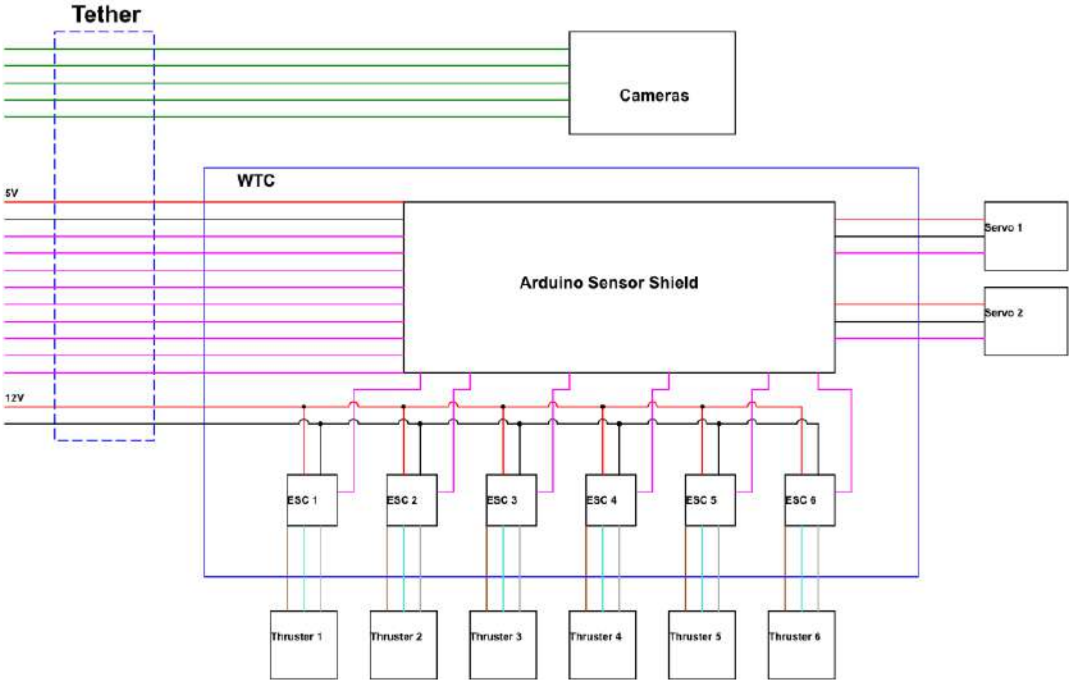
Software Flowchart



Surface Electronics



On Board Electronics



Tooling

Claw

At first we attempted to build a claw with three segments in each finger, each of different shapes. It was important for these shapes to fit the predesigned dimensions precisely for maximum effectiveness, as the segments would each be moving parts. As a result, the designed parts were given to a manufacturer to cut out, as they would be able to make the parts to a much greater degree of accuracy. However, technical difficulties resulted in a lengthy delay. Additionally, certain materials originally planned for the design were unavailable in Hong Kong. Ultimately, this design proved too impractical and complex to be put together, and was abandoned. Instead, a simpler, but still effective, two-finger claw was used. The claw operates using a servo that can be controlled by the pilot from the control box. A servo-powered claw was chosen over a hydraulic claw as we found a hydraulic system to be too complex and hence unreliable, while the servo system functioned well enough for the designated tasks. Furthermore, calculations revealed that the air inside the claw would create buoyancy issues that would require more weight to the chassis to gain neutral buoyancy.

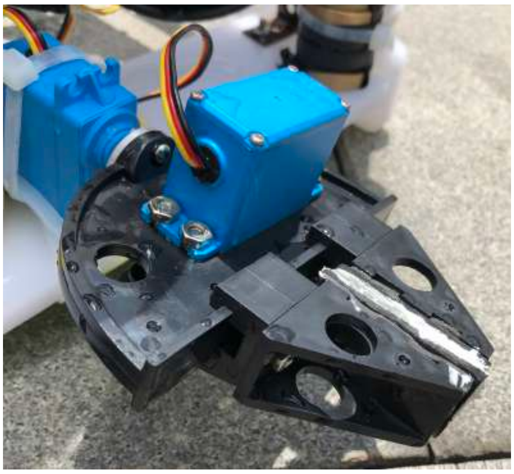


Fig 19. Claw

The servo is fastened to the handles of the claw, and can be rotated 180 degrees to open and close the handles. The claw handles can open up to 5 cm apart, which allows them to grasp a wide range of objects, as is necessary in the tasks. The entire claw itself is also mounted on a servo that allows it to turn 180 degrees, again controlled by the pilot from the control box. This allows our claw more flexibility in the tasks it can accomplish, as it is able to grasp objects at various angles due to the rotating ability provided by the servo.

The insides of the handles are lined with foam and further coated with silicon. The purpose of the foam is to provide a better grip as the foam is flexible enough to bend around the object. This also avoids putting unnecessary strain on the servo to avoid damaging it. The silicon increases the friction between the object and the claw handles, to prevent any object from slipping from the claw's grip.

The claw is positioned at the front of the ROV, fastened to a tooling panel at the bottom. This is an ideal position to pick up objects from the pool floor. It was clear that the claw would need to extend in front of the ROV in order to have a large enough range to interact with the vehicle's surrounding environment. However, to extend the claw too far out would have risked violating size restrictions and resulted in fewer points for the team; additionally, an excessively long claw would be unwieldy, impractical, and might even make it more difficult to balance the ROV. Eventually, we decided on positioning the claw so that it extends 14 cm out from the ROV, chosen as a compromise between the conflicting needs of range versus practicality.

Airbag

The airbag is critical for success in Task 1 and therefore much effort was thought into making it as simple and yet effective as possible. This would therefore be striking the balance between lift power and size. First, given the weight of debris in water (3.06kg) we calculated the minimum volume of air required to provide enough up thrust. 3L was then added to increase the speed at which the debris could be lifted. This volume of air was therefore optimal for our purposes: not too big as to impair the ROV's movements and vision but still large enough to provide sufficient up thrust.

Fig 20. Lift bag +Hand pump

A lot of thought was put into the design philosophy of the airbag. The airbag was constructed using a transparent bag with a screw lid. This was best as transparency was key to mitigating the problem of vision obstruction. Furthermore, the screw-on lids allowed for a waterproof and secure epoxy seal between the air tube and bag. A small air hole was punctured into the airbag so that we could dynamically adjust the amount of air we wanted in the airbag. This was better than using a valve as not only is it far simpler and cheaper, but it is also safer. If too much air was pumped into the airbag, this hole would allow air to escape releasing excess pressure and reducing the. The only downside is that because air would be constantly escaping from the airbag, we needed strong enough pump. After some calculations and online shopping however, it was determined that a strong pump would be much cheaper than an electronically controlled valve. Therefore, this design element was used.

Attached onto the airbag is a hook, shaped to be easy to attach onto the U-bolt attachments on the debris elements. The hook is complemented by a heavy weight and float at the top of the airbag to ensure that the airbag is always upright and stays attached onto the debris during the initial stages of pumping. Also attached to the top of the airbag is red tape in order to make the airbag easily identifiable - this was done for both safety and convenience purposes.

OBS

Both the OBS and connector are constructed with plastic because of its budgetary advantages, close density to water (Difference of 0.38 g/cm) and ruggedness. The two are connected using a 2.5m colourful string. It was decided that a colourful string would be best for identifying it - advantageous from both a safety and practical standpoint. The connector is held into the OBS using magnets. This is to ensure that the connector does not fall out at any time during the task. Furthermore, magnets were used instead of Velcro, because the strength of the magnets would help guide the connector into the OBS. There are two trigger mechanisms for the OBS: magnetic reed switch and manual. The magnetic reed switch is connected to a waterproofed motor that pulls out a metal rod releasing the OBS. A magnet inside the connector activates the magnetic reed switch. Therefore, once the connector is inside the OBS, the OBS will automatically be released. This clever release mechanism will save time and is far more reliable than having the ROV itself try and keep the switch open for a long duration. In the case that the magnetic reed switch mechanism fails, the OBS can also be released manually using a magnet to pull a metal rod out of the base, releasing the OBS. This dual method approach ensures that the OBS can be recovered.

Fig 21. OBS

Distance Measurement

Fig 22. Measuring Tape

To achieve the task of measuring the distance, we fastened a tape measure onto the tooling panel.
We selected the tape measure carefully. Size was an issue; the tape measure could not be too heavy, as this would be unwieldy and interfere with the balance of the ROV. Conversely, it had to be large enough that the measurement was easily visible on our camera screen, as we did not wish to waste precious time struggling to read the numbers on the tape measure. Eventually, after pool-testing different tape measures, we settled on a tape measure that would be large enough to read and yet not too heavy. Furthermore, the tape measure would have to have a mechanism at the end to allow it to fasten onto one end of whatever distance it was measuring. Most tape measures have a hooking mechanism at their end; we chose a tape measure which had a larger than average hook to ensure that it would be easy to use, making our distance measurement faster and more efficient.

Budget

At the beginning of the year, the team planned how we were going to design the robot. Research was done to learn about different materials to find the best design to complete the mission tasks. NOAA construction was made possible by the generous donation from the GSIS Foundation Ltd. We allocated our budget of HK$20,000 (US$2,574.56) into three stages of building our ROV: Design, Development and Production. Whenever a team member purchases vital components to our ROV, receipts were collected and tracked with the budget. This was done through the help of a budget spreadsheet we created which was uploaded to Google Drive, so that it would be accessible by our team members and sponsors. Team members were alerted every session as to what percentage of the total budget had been spent, to keep within our budget guidelines.

Equipment	Allocated Budget (HKD)	Amount in HKD	Allocated budget (USD)	Amount in USD
Camera	5000	4245.9	636.94	540.88
Chassis	4000	2493.1	509.55	317.59
Control Systems	4000	3087.5	509.55	393.32
Fasteners	1000	919.5	127.39	117.14
Prop	1000	227.2	127.39	28.94
Tooling	1000	715.5	127.39	91.15
Wiring	2000	1365.0	254.78	173.88
Shipping	2000	1351.3	254.78	172.1
Total:	20000	14414.0	2574.77	1835.0

Camera

Date	Item	Amount in HKD	Amount in USD
5/3/18	Fishing Camera	$4,245.94	$540.88

Chassi

Date	Item	Amount in HKD	Amount in USD
19/10/17	Chassis	$107.10	$13.64
30/10/17	Chassis	$71.40	$9.10
3/11/17	Chassis	$240.38	$30.62
6/1/18	Chassis	$9.52	$1.21
7/1/18	Chassis	$41.65	$5.31
15/1/18	Chassis	$273.70	$34.87
24/2/18	Chassis	$380.80	$48.51
24/2/18	Chassis	$380.80	$48.51
12/3/18	Chassis	$380.80	$48.51
15/3/18	Chassis	$380.80	$48.51
26/3/18	Chassis	$226.10	$28.80

Control Systems

Date	Item	Amount in HKD	Amount in USD
7/9/17	4 in 1 ESC 12A	$701.19	$89.32
9/9/17	Arduino MEGA 2560	$92.82	$11.82
9/9/17	Waterproof Junction Box	$131.95	$16.81
17/9/17	4 in 1 ESC 25A	$283.87	$36.16
23/11/17	Arduino MEGA 2560 Sensor Shield	$76.16	$9.70
23/11/17	Blue Robotics ESC	$1,562.00	$198.98
23/3/18	Arduino Joystick (3*3)	$142.80	$18.19
26/3/18	Arduino Joystick (1*5)	$61.05	$7.78
26/3/18	Arduino Dial	$35.70	$4.55

Fastener

Date	Item	Amount in HKD	Amount in USD
9/9/17	Waterproof Solder Seal	$83.18	$10.60
16/11/17	316 Hex Bolt kit	$42.60	$5.43
16/11/17	302 M4 Hex Inserts	$14.28	$1.82
16/11/17	302 M3 Hex Inserts	$11.90	$1.52
25/1/18	3M Dual Lock 400 10M	$767.55	$97.78

Props

Date	Item	Amount in HKD	Amount in USD
3/3/18	5L Collapsible Foldable Water Bag	$54.26	$6.91
3/3/18	Multi-purpose Foot Air Pump	$118.73	$15.12
3/3/18	10 pcs 2*14mm Magnetic Reed Switch	$36.82	$4.69
3/3/18	S-type Steel Measuring Tape	$17.37	$2.21

Toolin

Date	Item	Amount in HKD	Amount in USD
25/1/18	Black Robot Clamp Cripper	$286.79	$36.53
9/9/17	2 pin Waterproof Connector Cable	$18.18	$2.32

Wiring

Date	Item	Amount in HKD	Amount in USD
9/9/17	2 pin Waterproof Connector Cable	$18.18	$2.32
9/9/17	2*20 pin Connector	$3.61	$0.46
9/9/17	2*30 pin Connector	$5.94	$0.76
9/9/17	8 pin Waterproof Connector	$42.84	$5.46
9/9/17	4 pin Waterproof Connector	$33.32	$4.24
9/9/17	3 pin Waterproof Connector	$154.70	$19.71
9/9/17	3*5 pin Male/Female Connectors	$24.99	$3.18
9/9/17	4 pin Power Waterproof Connector	$41.65	$5.31
12/9/17	16 pin Waterproof Connector	$110.67	$14.10
19/9/17	1m 24 AWG Silicon Wire	$57.81	$7.36
19/9/17	3m Green 24 AWG Silicon Wire	$23.19	$2.95
19/9/17	3m Yellow 24 AWG Silicon Wire	$23.19	$2.95
19/9/17	3m Blue 24 AWG Silicon Wire	$23.19	$2.95
19/9/17	3M Orange 24 AWG Silicon Wire	$15.92	$2.03
22/11/17	40m cat 7 flat cable	$320.00	$40.76
26/11/17	10mx5colours 30 AWG silicone wire kit	$109.32	$13.93
26/11/17	10 AWG yellow silicone wire	$135.47	$17.26
26/11/17	10 AWG white silicone wire	$135.47	$17.26
26/11/17	2 pin Power Waterproof Connector	$11.75	$1.50
30/11/17	16 pin Waterproof Connectors	$73.78	$9.40

Expenses Breakdown

Safety

Company Safety Philosophy

Safety was our predominant concern throughout the entire process, even before we started actually building the ROV. Our team took precaution to design a ROV that would operate safely, as well as to ensure that we were building our ROV with precaution.

We had a few new members on our team who had no experience on building a robot before, and as a result we took the responsibility of teaching them on how to operate power tools safely, including soldering irons, drills and jigsaws, and ensuring their proficiency with the tools. We also made sure that there was at least one experienced member monitoring the newer members when they worked with power tools.

Protective equipment, such as safety goggles and gloves, was worn at all times while operating power tools, and our team ensured that our working area was well ventilated while we were using toxic materials. All our team members wore full length trousers and close toed shoes, and when applicable, had their hair tied back, while working on the ROV.

Safety checklist:

- ✓ No exposed wires & propellers
- ✓ Wires securely connected
- ✓ Any attachments to the ROV securely fastened on
- ✓ Tether properly attached
- ✓ ROV securely connected to the battery
- ✓ All electronics functioning properly
- ✓ The lid of the watertight compartment securely fitted on

Safety protocol:

- ✓ Long hair tied back
- ✓ Gloves worn when handling toxic materials
- ✓ Safety goggles worn when working with power tools
- ✓ Parts to be worked on held down by a clamp
- ✓ Area properly ventilated when working with solder
- ✓ Area around the control box kept free of any tripping hazards

Vehicle Safety Features

The ROV itself is also designed for maximum safety. The propellers are shrouded to prevent injury, sharp edges are all filed down, and all connections are made waterproof by properly insulating them with heat shrinking tubing as well as epoxy. All electronic components are kept inside a watertight compartment, which was tested multiple times for leakage. The attachments on the ROV have been tested to ensure that they stay fastened to the chassis, even when the ROV is moving at high speeds. The ROV itself is small and light, so it does not disturb the environment while carrying out its tasks.

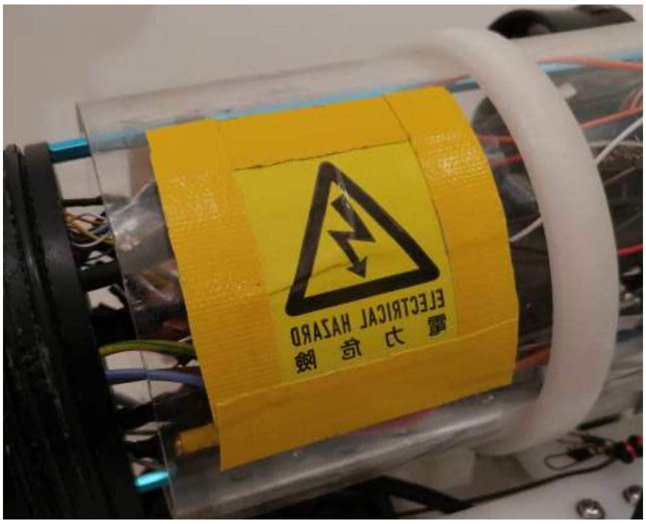


FIG 23. WARNING STICKER ON WTC

Fuse Calculations

Control Components	0.5A
Thrusters	6.2A
Cameras and Monitors	3.7A
Servo	2.8A
Full Load Current	13.2A
150% Overcurrent	19.8A
Appropriate Fuse	20A

The importance of safety is also apparent topside. There is a single inline 20 amp fuse no more than 30 cm from the main power supply. This fuse is essential in reducing the risk of damage to the ROV itself, its pilots as well as even divers. All connections from and to the control box are securely attached by bulkhead connectors, ensuring that all electrical wiring stays intact and that there are no safety risks if any of the connections are pulled at.

FIG 24. 20 A FUSE

FIG 25. BULKHEAD CONNECTORS

Troubleshooting

From experience from last year, many of our team members understood the importance of establishing a systematic troubleshooting process in order to save time during development, and especially the product demonstration. These steps also allow for non-electrical or software engineers to troubleshoot themselves. The following are potential problems and solutions.

Thruster and tooling -

1. Check if fuse is blown
2. Check that Arduino is on
3. Check that connections to breadboard, Arduino and joysticks are secure
4. Check watertight container for leaks
5. Check if servo/DC motor is somehow stuck
6. Check if tooling bulkhead is properly secured
7. Check if ESC's are online
8. Make sure Arduino sensor shield is blinking red
9. Open watertight compartment and make sure all connections are secure

Camera -

1. Check if fuse is blown
2. Check that all monitors are turned on
3. Re-secure camera to monitor
4. Check resistors and connections to main power supply
5. Switch camera and monitors around to see which component is faulty

Challenges Faced

Technical

Even though this is not the first time building a ROV, new technical challenges are always a hurdle. The largest technical hurdle was designing our chassis. We made multiple attempts, but each had their own flaws. Some were too big - and when we shrunk the design, fitting the thrusters inside the chassis became a problem. Furthermore, the unreliable 12V power supply provided by our school was another technical challenge. Whenever we wanted to draw power quickly, the 12V power supply would not be able to provide enough current. This would cause a system-wide shut down where all thrusters would stop for a few seconds. This was a massive problem, as we did not have smooth motor control. In order to adjust for this, we altered the thruster values in the code to limit power if it reached a certain threshold.

Non-Technical

Time was a major non-technical challenge we faced from day 1. Due to everyone's busy schedules we found it difficult to find a good time to meet up. Furthermore, the school only allowed us to use its facilities once a week after school. This rigid schedule greatly limited the time we had to work on the ROV. In order to overcome this, we decided to move the working space into someone's garage. This would allow for a more flexible working schedule.

Because we were working in a garage, a lot of the equipment we needed to build the ROV was often not accessible, so we needed to order them online; items ordered online took a long time to arrive, resulting in moments where some of us could not complete our tasks because of the lack of items needed.

Lessons Learnt

Technical

This year, we learned about the importance of making more use of CAD software. During this endeavour of developing NOAA, we designed and redesigned the chassis many times. Often, a chassis would fail because we did not take into consideration all the drill holes required for assembly. Therefore, we made it common practice to CAD the drill holes during the CAD and designing process in order to make sure everything fit before the CAD file was sent off to a manufacturer.

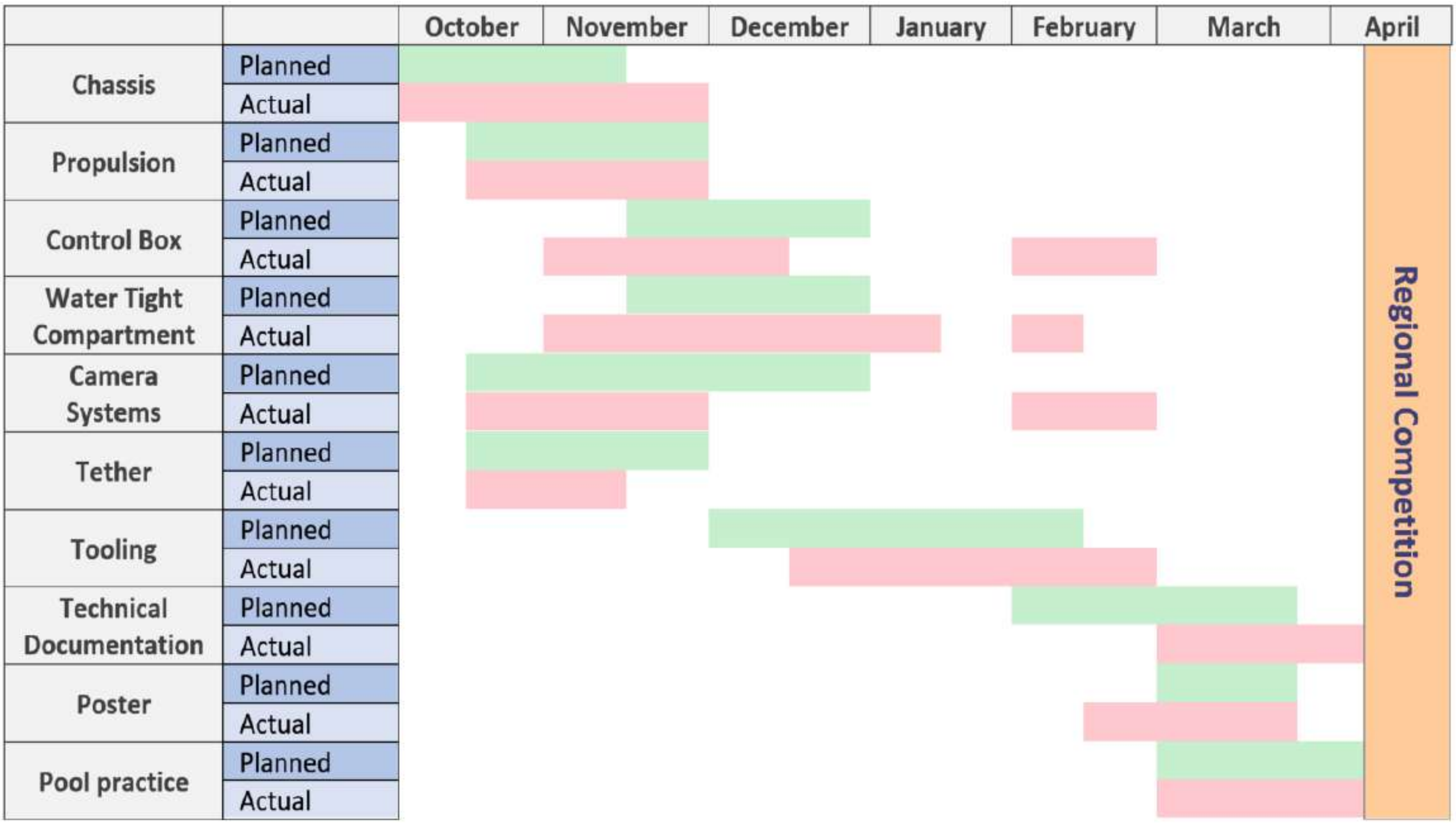
Interpersonal

One of the most important interpersonal skills we have learned both as a team and individually is how to trust and rely on each other. At first, we would often argue about design choices. As we continued to work together however, we realised each other's strengths and weaknesses. Recognising these strengths and weaknesses, meant that we were able to trust certain team members with certain tasks, as we knew that they would be able to execute better than the rest of us. Not only did this increase the quality of work but it saved us precious time as we spent more time working instead of debating and discussing. This was integral in becoming a more efficient team and was definitely the most lesson learned from this experience.

Future Improvements

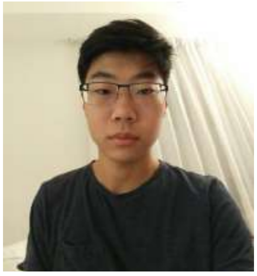
Restricted by budget and time, the following changes are improvements that we could not implement. While the six monitor video system is great for being able to see in almost all directions, housing the entire system inside a pelican case means that each monitor is very small. If given more time and money, we would love to add much nicer monitors that make the piloting experience even more enjoyable. Another possible improvement could be a gyroscopic centring system. This would allow for the ROV to resist currents in the water. This would be optimal especially for working in rivers and oceans where currents can be very strong. We were not restricted by budgetary means, nor technical means to implement this. In fact, we had already bought components and did plenty of research on how to implement such a system. We were not able to implement this feature due to the limited time we had but installation of such a system would be very possible if given more resources by the University of Washington.

Project Management



Reflections

Elliot Jinoo Hong, Class of 2019



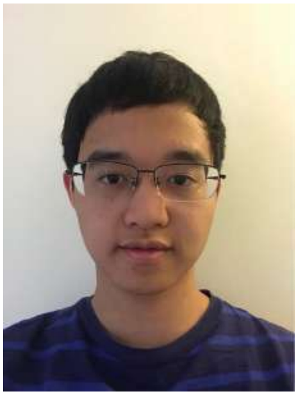
“Because of my prior experience with robotics and role as CEO, I felt that it was my responsibility to help others on the team. Although challenging, the entire process, both development and testing, was very rewarding. What was especially fulfilling was being able to work in a team for such a long project. Very rarely at school do we get the opportunity to experience what it is like to join the workforce. ROV for me however, simulated a job in engineering and technology, giving me a glimpse into a possible future of mine, and for that I am very grateful.”

Arushee Kadam, Class of 2019

“My goal this year in ROV was to learn as much as I could about engineering and its practical applications. I have always been keenly interested in science, and in recent years, a fascination for engineering has sparked in me as well.

ROV was a fantastic opportunity to develop these interests and learn so much about the building of a robot. Additionally, I learned to work together with my team to solve whatever problems we encountered during the process, whether big or small. Being part of our ROV team was an inspiring and unforgettable experience which has given me skills that will definitely help me throughout my life.”

Jeffrey Chak, Class of 2019



“I am the only member of the team who had not previously participated in a ROV competition. While this has been challenging for me, especially since I had had no prior experience with power tools, electronics and the like, I have been able to benefit greatly from the experience and support that the other members of the team have provided, and I have learned a lot of skills and techniques as a result. I have also been able to build on my coding ability, and have gained experience through debugging the software; and writing in C Sharp, which I had not previously done. Overall, being in the team has been an enjoyable and valuable experience for me.”

Audrey Yung, Class of 2020

"This being my second year of ROV, I was set on learning more about the electrical and programming aspect of the ROV. Physics and more generally, science has always been an interest of mine and although I was proficient in understanding numerous theories, I lacked physical experience in engineering. Even though I liked doing theoretical science more than practical work, I was fascinated as how such theories could be applied to the world of technology. By joining this team of remarkable people, I learnt lots of new skills and understood the interpersonal issues of working in a team. There were several ups and downs before we successfully accomplished our mission to build a ROV. Overall, the experience was very enjoyable and I look forward to another year of tedious yet satisfying ROV work.

Cyrus Lam, Class of 2020

This was my second time participating in the robotics competition, and I can say without hesitation that it was one of my most worthwhile experiences of the year. I learnt a huge amount in one year, in various aspects of robotics, from designing a ROV, to programming the controls, to the basic skills of using power tools. Not only did I further my interest in engineering, I also took away several practical skills that I would never have gotten a chance to learn had I not participated in this activity. Moreover, I also learnt that to move past the difficulties our team faced to build our robot together. This has been a fantastic experience, and I would definitely want to take part in this competition next year as well."

ACKNOWLEDGEMENTS

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Competition Organizers

Marine Advanced Technology Education (MATE)
The Institution of Engineering and Technology (IET)