The 14th IET/MATE Hong Kong Regional of the MATE ROV Competition

THE IET/MATE HONG KONG REGIONAL – UNDERWATER ROBOT CHALLENGE 2019

Technical Documentation

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Abstract

Upon the request of MATE and Eastman Company for proposals of a remotely operated vehicle and crew that can operate in the freshwater environments of Boone Lake, Boone Dam, and South Fork of the Holston River, we carefully designed our ROV for the proposal. The mission consists of three categories: **ensuring public safety**, **maintaining healthy waterways** and **preserving history**.

Our ROV inherits the advantages of our previous design. It is capable of tackling tasks including ensuring the public safety by inspecting the foundation and repairing damaged parts of a dam with a micro-ROV. To maintain healthy waterways, we monitor water quality, determine habitat diversity, and restore fish habitat. For preserving history, we recover a Civil War era cannon and mark the location of unexploded cannon shells.

Our ROV is controlled by joystick and switches. All equipment is assisted by well-designed electrical communication and tested underwater. Our ROV is equipped with:

1) Four highly efficient brushless thrusters for mobility which are directly controlled by thruster commanders without delay.
2) Four high-resolution cameras which provide the driver various views simultaneously for identification and determination purposes.
3) A rotatable robotic payload for holding and grabbing objects firmly for transport and release.
4) A micro ROV with cable retractor for inspection inside drain pipes.
5) A metal detector which can distinguish metal objects from other types of objects.

This report lists out the development process and the design details of our ROV, including the safety, troubleshooting techniques, further improvement, reflection and project budget.

(249 words)

Table of Content

I.Photos of ROV

Outlook of the our ROV (KTS-Dolphin)

Fig 1.1 Perspective View of ROV

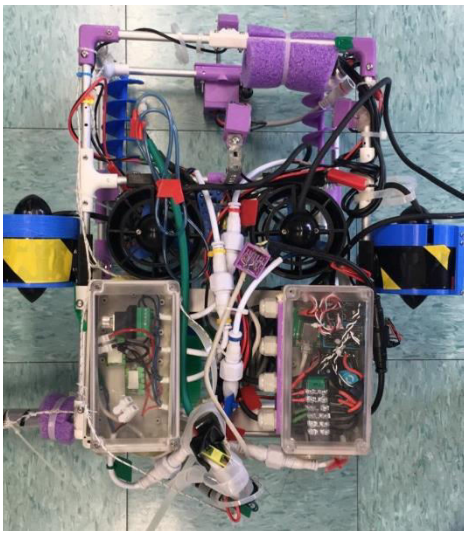


Fig 1.2 Top View of ROV

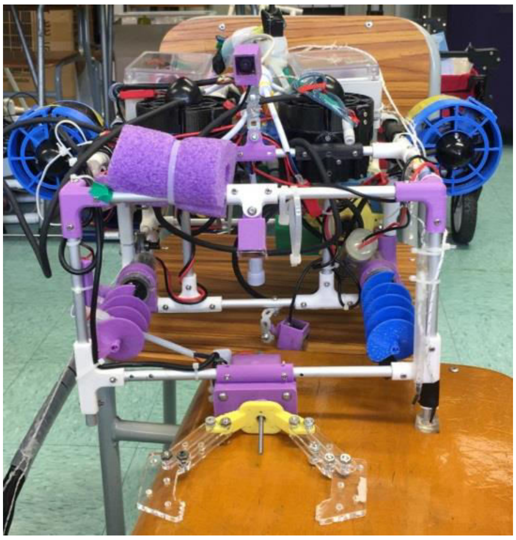


Fig 1.3 Front View of ROV

Fig 1.4 Side View of ROV with Micro-ROV

II. Design Rationale

Modified from the previous design, most of the components of our ROV are newly innovated and constructed by many 3D-printed parts. As 3D-printing materials are light and can be flexibly shaped, we utilized it to print joints connect the aluminum pipe which forms the ROV frame, as well as a payload (pair pliers), two helix droppers for releasing makers and adjustable cameras mounts, which makes the ROV compact, flexible in water, and efficiently operational in demonstrating the tasks according to the MATE ROV Competition and the Eastman Company required specifications. Further, 3D printing materials are inexpensive, which can save cost of ROV.

Our ROV consists mainly of separated water-proofed boxes for storing electronic components, four water proofed thrusters (two for 4-directional movement and two for vertical movement) a rotatable robotic payload tool (e.g. a mechanical gripper).

The major concern of the design rationale is that the movement of the ROV under water is too slow which is affected by two factors: water resistance and power supply. However, these factors are constant in the competition. 12V power and water resistance in a swimming pool are environmental factors which cannot be changed or enhanced. As a result, the efficiency of the thrusters and the streamline design of the ROV are the two important design rationales to encounter the issues.

Building a highly efficient underwater ROV is our major objective, as we have only 15 minutes to complete all the tasks. Our experience from previous years has taught us that using brushless motors is much more efficient than brushed motors. The efficiency and speed is greatly increased in that scenario. The streamline designed foam cover of the ROV helps reduce the water resistance problem. The foam provides a strong upthrust force under water and provides greater buoyancy for the ROV. Natural buoyancy is always achievable but if the ROV is too heavy, the movement of the ROV will be negatively affected. As a result, we chose to construct our ROV from aluminum pipe in order to reduce the weight so that it can move faster in all directions.

This year most of the tasks need different props to help us to complete them (e.g. a mini ROV, Helix dropper). In addition, we designed an adaptor on our payload for specific tasks, like releasing fish.

For off-shore controlling, the control box is too bulky. To make it smaller with full functional, a joystick and buttons were adopted to control all components of the ROV.

III. Vehicle Core System

A. Mechanical

1. Framework

Lightweight

To combat water resistance, we have minimized our robot frame such that every component, including two Blue Robotics T100 and two T200 thrusters, the payload, four cameras, and the container of all electronic devices are only connected and fixed onto a rectangular frame constructed by aluminum pipes. The height of the ROV has been greatly reduced from 0.4m to 0.25m compared with previous years.

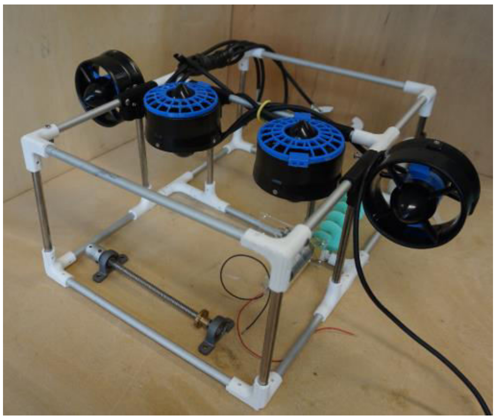


Fig 3.1 Body frame of the ROV

Construction flexibility

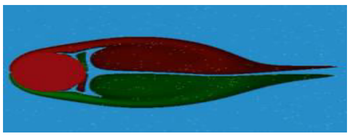
Fig 3.2 joins made by 3D printer

The aluminum pipes joined by 3D-printed joints and are secured by strong-mounting- powered M3 screws, making the framework rigid yet detachable and modular. The frame can be easily modified by detaching and adjusting the position of various components. This provides flexibility in polishing our design. Also, the materials can be used, which save cost and is more eco-friendly. Regarding the materials used for the joints, 3D-printing materials are used due to its flexibility to be created in any shapes and its low expenses which maintain the ROV a reasonable budget

Reducing water resistance

In order to reduce the fluid resistance of water, we use aluminum pipes which are light and cylindrical instead of rectangular as the material for framework construction. The advantages are a lighter weight, reduced water resistance, hence less power consumption and faster movement.

Figs 3.3a Aluminium pipe



Figs3.3b simulation in cylindrical shapes

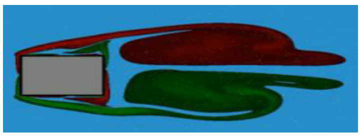


Fig3.3c simulation in rectangular

According to the simulation, the fluid drag of the cylindrical pipes is less than the other shapes in same condition.

2. Buoyancy

a) Water-proofed plastic box and foams for ROV buoyancy

Attaining neutral buoyancy is crucial as it allows effective movement of the ROV. To compensate the weight of the ROV and achieve neutral buoyancy (buoyancy force = apparent immersed weight of the ROV), the frame and the tether of the ROV are fabricated with a water-proofed plastic boxes, sealed PVC pipes and foam. They are placed on the top of the ROV to provide upthrust to counteract the weight of the ROV. Their positions will be adjusted and foams will be added to balance the left and right of the ROV. It allows the ROV to maintain a state of neutral buoyancy which ensures a better movement of the ROV. Further, swimming foam is cheap, easily accessible, which made it an ideal material for maintaining the buoyancy of the ROV.

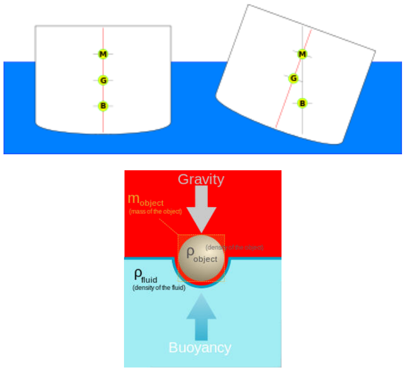


Fig 3.4a Buoyancy force balanced apparent immersed weight

As a result, the ROV attains a balanced net force in which neutral buoyancy is achieved and the ROV is able to consistently maintain the desired water level. The position of installation of the main control box was carefully selected to be at the upper center part of the ROV body and in the middle of two thrusters so that center of buoyancy can remain lower than the center of the gravity of the ROV. This helps prevent imbalanced torque and tilting of the ROV, without delivering extra water resistance produced by the movement of thrusters. The ROV was put underwater to test its buoyancy. Different amounts of foam were attached until it reached neutral buoyancy and was able to stay static underwater after several testings.

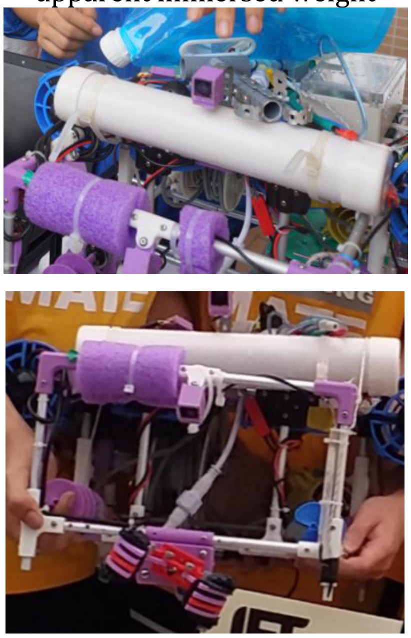


Fig 3.4b Buoyancy supported by plastic boxe, PVC pipes and foam

b) Buoyancy on the Tether

In addition, the ROV is connected by a 20-metre long tether, as well as other wires which are connected to our electronics devices. The weight of the tether will affect the buoyancy of ROV, too. Hence, we also wounded the tether of our ROV with some foam to ensure a neutral buoyancy of the tether. Since foam is light in weight, when foam is wrapped around the tether, it is less dense than water and gives upthrust to balance the weight of the tether. Testing is carried out to find state of neutral buoyancy in which a physical body's average density is equal to the density of the fluid in which it is immersed.

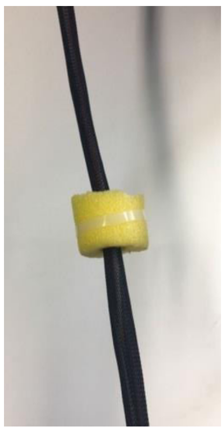


Fig 3.5 Tether wrapping by foams

(Photo credit:Sam Wong)

3. Propulsion

3.1 Position of propulsion system

Due to its compact and light yet powerful, we use Blue Robotics T100 thrusters as our propulsion system. Previously, we used six thrusters to build our ROV last year. The Omni-arrangement of the thrusters provided movement for all directions, but it reduced the efficiency of the movement at the same time. As a result, this year we want our ROV to be more compact and move efficiently. Several improvements have been made.

First, we have reduced the number of thrusters from 6 to 4, by giving up the omni-arragnment, only four thrusters are used. Two of them were placed horizontally along the sides of the ROV and are responsible for the forward-and-backward and left-and-right turn movements of the ROV. The other two were placed vertically at the middle of the ROV body to facilitate the vertical movements (sink/float). As a result, KTS-Dolphin can use the main power effectively under water. The only trade-off is that the KTS-Dolphin cannot be shifted horizontally (shift towards left and right).

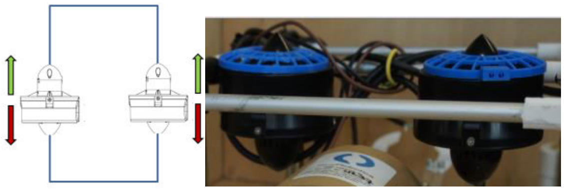


Fig 3.6 Propulsion system (vertical movement)

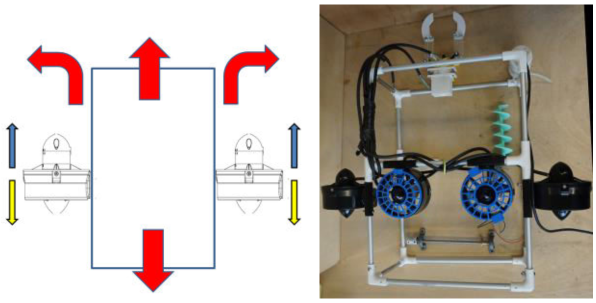


Fig 3.7 Propulsion system (4 directions movement) and Thruster position

We mounted the 4 thrusters onto ROV firmly onto the aluminum pipe of the frame body by 3D joins made by 3D printer and eventually attach them. KTS-Dolphin can therefore move in any direction and tackle missions efficiently.

3.2 Better performance

Second, we gave up T200 and choose a less power thruster but still highly efficient, the Blue Robotics thruster T100. T200 thruster is designed for 24V power supply, so the drawing current from the main 12V power supply is higher than it needed. We choose blue robotics thruster T100, so that it will not draw too much current from the main power supply. Hence, the power supply can provide steady and adequate current for other components.

The T100 thruster provides 5.2lbf (23N) thrust when operate in 12V and 2A. The maximum forward thrust and reverse thrust of nearly 10.4lbf (46N) each. It is good enough to handle ideally with the approximately 40N payloads as required in each task and to lift up a cannon which is much heavier.

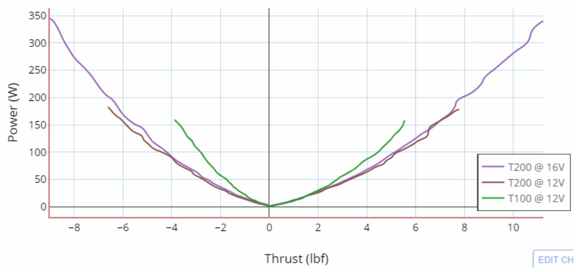


Fig 3.8 thruster: Power vs Thrust Comparison[1]

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[1] https://www.bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster/

3.3 Waterproof work

We have been examined that the core of the T100 thruster is sealed and protected with an epoxy coating and it uses high-performance plastic bearings in place of steel bearings that rust in saltwater. This guarantees a better performance in the ocean.

3.4 Safety—protective guards

For safety concerns, we not only carefully seal every wires, but we also create some protective cover by 3D printing using an 3D filament to prevent others from incautiously put their fingers into the motor blades and twisted the sea plant.

Fig 3.9 Thruster without protection.

Fig 3.10 3D-printed protective cover guards for both sides
(Photo credit:Sam Wong)

B. Electronics

1. Electronic speed control (ESC)

For controlling brushless motors, ESC must be used. An ESC is an electronic circuit used to vary speed and direction, and also used as a dynamic brake for the electric motor. Our team used the ESC to receive the PWN signal thruster commander. The motor will turn clockwise or anti-clockwise according to the rapid switch of the transistors. This allows basic operation of the Blue Robotics thrusters and controls the movement of KTS-Dolphin.

Fig 3.11 Blue Robotics Basic ESC v3 for Thruster

Our first attempt was to use the Hobbywing ESC as the thrusters' controller. However, the ROV experienced a slight malfunction because it had a poor heating design which caused overheating of the circuit. Therefore, this year we used the basic ESC which has a low-heat design optimized for a cooling environment.

2. Blue Robotics Thruster commander

For many years, we used two Arduino microprocessor boards connected with RS485 to send control signals to regulate the movements of the thrusters. However, the delay of signals made controlling the ROV difficult. Thruster signals also have to send other control signals as well. This led to a signal jam in some cases. As a result, we discarded using Arduino and now use a thruster commander to control the ESC directly via a joystick with a potentiometer this year. The thruster commander is used independently for other signal components in which signals are sent directly between the joystick and thrusters instead of gathering into one single microprocessor board. Consequently, the risk of signal collision with the other components decreased and a stable signal transfer is retained. The joystick contains two 10K ohm variable resistors. By changing the size of the resistor, sizes of output voltage vary which act as signals to control the ESC and hence the speed and rotational direction of thrusters. Apart from controlling the ESCs, the commander also allows the ROV driver to control the steering of the ROV effortlessly.

All signal wires are connected with a UTP cable which has 4 twisted-pairs of cables with a waterproofed plug leading to a joystick on the surface. As a result, the movement of the ROV can be controlled through one UTP cable.

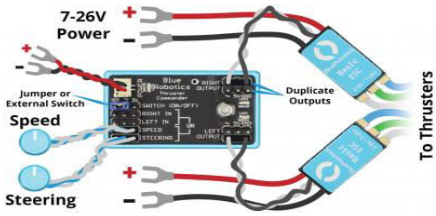


Fig 3.12 Thruster Commander
(Photo credit: Blue Robotics)

3. Main Control box of ROV

We have already discussed the major disadvantage of using RS385 in the Arduino microprocessor. We gave up using Arduino to control the ROV via a PS4 game pad and now use the thruster commander to control the ESCs. We use joysticks to control movements of ROV. The opening and closing of payload, rotating robotic arm and helix dropper are all driven by motors. Motors are directly controlled by Switches which respond very quickly. As a result, the pilot can control the movement of the ROV as well as other tools very effectively.


Fig 3.13a Main ROV Control panel


Fig 3.13b Main ROV joystick
(Photo credit: Isaac)

4. Payload with rotating Arm

Payload is an essential tool for picking and grabbing objects to achieve various tasks. When encountering the design of the payload, shapes and mechanism are specifically designed according to the shapes, position and materials of the objects that are needed to grab in the missions.

4.1 Design of gripper

Payload is designed for picking up objects and grab the tools for the ROV. In previous design, we used metals as the primary material for the pliers, but they were heavy and hard to shape. Sometimes, it stuck into the gears when operating the gripper. Using servo motor cannot grab object firmly. It is because servo motors have to keep providing a force generated by electrical energy to sustain the force to hold object firmly. With the evaluation, we design to use worm gear driven by a motor which give very high strength to push the arm outward or backward accordingly. Hence the arms can be opened or closed according to the rotating direction of the worm gear and the motor.

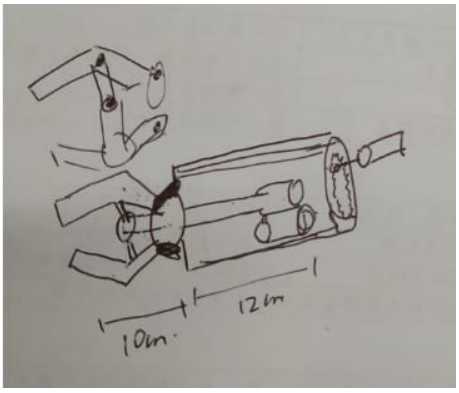


Fig 3.14a Draft design of the ppayload

The gripper is operated by a screw cap connected with two joints and a long screw. When the screw rotates clockwisely, two fixed joints pull down and the gripper tightens up. In contrast, when the screw rotates anti-clockwisely, the two fixed joints rise and the gripper opens. These allow the gripper to hold and release objects for completing different tasks. The screw is rotated by the motor attached to a 3D-printed platform perpendicular to the gripper orientation. The motor is then waterproofed by putting epoxy into the cylindrical tubing, filling the tubing with petroleum jelly, and sealed the tube with epoxy to ensure that no water can leak into the motor.

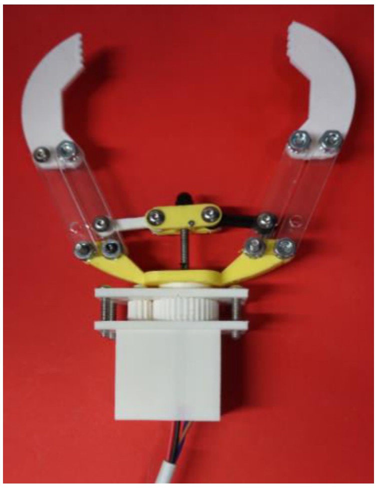


Fig 3.14b Payload

With the worm gear, the gear ratio is highly increased; therefore, it is impossible to change the state of the arm without controlling of the motor. As a result, the gripper can hold object firmly even without electrical power.

Fig 3.14c 3D design

4.2 Rotatable arm

As the payload is one of the main tools for accomplish tasks, it is preferable to be able to rotate freely. Therefore, we tried to implement a rotation system on the payload. We tried to reuse some different type of gears, but all of them did not suit our needs.

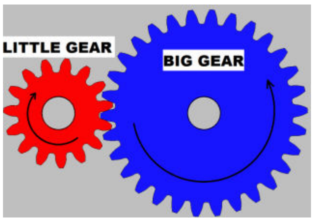


Fig 3.14c Gears

Eventually, we design the rotating system by 3D design software. The grabber is design to have a large gear with more teethes attached in the cylinder. And a small gear with less teeth is controlled by a motor is put next to the large gear such that when the small gear rotates, the large gear of the gripper will also be rotated. The design increased the gear ratio and so as the force. This make the grabber rotated slowly which is a merit for changing to the desired angle. Similar to the motor of the gripper system, the motor of the rotation system is also waterproofed by the same method. The wires connected to the control unit in the ROV via a waterproofed plug. Therefore, the gripper can grab the thing vertically and horizontally, which gives us an advantage to pick up things in an easy way.

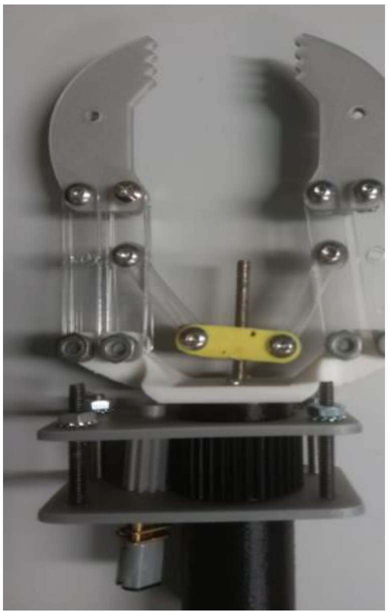


Fig 3.14d Payload with rotatable system

This design of gripper reduces the size and weight of the system greatly. It also enables the ROV to pick up things more easily. A lot of time is required to make a gripper system that functions properly as a minor mistake can ruin the whole gripper system and even affect the tasks.

4.3 Waterproof work

The motor was waterproofed by putting epoxy into the cylindrical tubing, filling the tubing with petroleum jelly and sealing the tube with epoxy to ensure that no water could leak into the motor. The wires are connected to the control unit in the ROV via a waterproofed plug. Therefore, the gripper can grab objects vertically and horizontally, which allows us to easily pick up objects. This is an obvious advantage.

5. Camera

5.1 Positions and mechanism

To facilitate effective vision with the ROV, it is equipped with four cameras. Two of the cameras are on top of the gripper which focuses on the target object of the payload and gives a front view. One is placed vertically so as to view the ground, which helps the pilot locate the position of the rubber tire that is required to be removed in task 2. One overlooks the two specific helixes (which will be mentioned in report p14, Mission Specifics), and allows better hand-eye coordination between manual operations and the helix in the placement of colored markers as required in task 3.

The cameras are connected to a LED monitor. The monitor is divided into four sections by a video splitter and displays real time images captured by the cameras. The wide vision provided by the four cameras not only assists product demonstration, but also allows the pilot to effectively operate the ROV in order to perform specific tasks in dam restoration work in real world.

Fig 3.15c Image displayed in LED monitor

5.2 Waterproof work

Each camera is waterproofed by placing it into a 3D-printed container, entirely sealed by epoxy to ensure that no water can leak into the motor.

5.3 Interference reduction

A capacitor has been added to reduce the interference of current. When the thrusters are being switched on and off, a sudden rapid change in amount of current leads to an unstable current supply to the camera, resulting in signal interference and a blurred image. Use of a capacitor instantaneously stores the excessive voltage delivered by the thrusters, hence stabilizes the current and maintains a clear image.


Fig 3.15b Water-proofed Camera

6. Waterproofed electronic components and plugs

We use **waterproof plugs** (waterproof performance of IP65 (International Protection Code) to connect wires from the ROV to the surface control box. The 4-pin water proof plug is also easy to replace and the cable management could be easier that also simply the work.

The **waterproof box** is used to store all electronic components, like ESC and the thruster commander. It is useful for protecting the electrical circuit and avoiding electric shock. The box is designed for easy replacement. A broken part can be replaced in a short time. Or if there is a main issue for the circuit inside the box, it can be replaced with a new one without disassembling other components. That makes repairs easier and more user friendly.

In addition, the waterproof box and plug also avoids potential human error caused by incorrect wiring. The dull edge on the box helps ensure less harm to humans. This is useful for us since there are many wires we need to use for different aspects, and they may twist together and get tied up. We wasted much time in the past fixing such a problem. Regarding the holes for cable connection in and out of the box, we also sealed them with an **AB Proxy agent** to make them waterproof.

We also poured **epoxy** into our electronics. Epoxy resins are a class of reactive prepolymers and polymers which contain epoxide groups. They are ideal for waterproofness. This ensures a better insulation between the devices and water and allows the ROV to function in a more stable way.

Fig 3.16a Waterproofed plug (cross section)

Fig 3.16b Waterproofed plug

7. Mission Specifics

A number of tools were specially designed to accomplish the tasks. These include a Micro-ROV, temperature sensor, metal detector, releasing grout device, helix dropper, tire grabber, trout fry transporter and automatic image recognition system. We reuse the temperature sensor other tools were newly built.

A) Temperature sensor (used in task 2)

A high precise temperature sensor is used to measure the water temperature. It is affixed in front of the gripper so the sensor can extend to the specific area and record an accurate temperature. The reading is shown directly on the data monitor so the members can accurately determine and monitor the temperature of the region.

Fig 3.17a Temperature sensor

B) Metal detector (task 3)

Fig 3.17b Metal detector

The metal detector will be used to determine the make-up of the cannon shells. It is fixed to the side front of the frame. When our device detects metal material, it closes the circuits, and the light turns on. If it is a non-metal, the circuit remains open and the indicator light goes off. The mechanism is done by induction. The device will induce a current to the object. If the object is metal, it will generate a current back to the detector by induction. Once the detector detects an external induction current, it discerns whether it is a metal or a non-metal.

C) Releasing grout device (task 1)

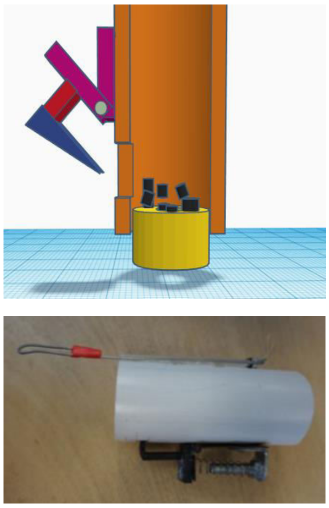


Fig 3.17c Releasing grout device

The device is built for inserting grout into voids underneath the dam. It is attached at the bottom of ROV. The service composed by a trigger mechanism. When the iron bar touched by bottom part of the plastic cup (simulation of underneath the dam), the knot will be lift up and the material will be released and grout the trash rack. Before we deploy this device, we will first fill some blocks (simulate the materials needed) and a 3D-printed objects to lock the threshold. When all parts are securely contained inside the cylinder, it will transport underwater and grout and repair the trash rack.

D) Helix dropper (task 3)

Fig 3.17d VendingMachine

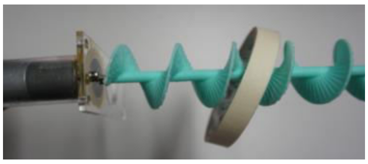


Fig 3.17e Hexlix dropper

Inspire by the design of vending machine and Archimedes ' screw, we built two helix droppers for dropping two kinds of markers. Two motors are attached on two 3D-printing helixes. When the motor rotates clockwise, markers hung on the helix will be pushed/guided to the end of helix and dropped onto the target area.

The motor was waterproofed by putting it into acrylic tubing, filling up the empty space inside the tubing with petroleum jelly and sealing the tube with chloroform. In addition, some AB-Proxy was added to the contact areas between the tube and the acrylic plate to ensure that no water could leak into the motor.

E) Micro-ROV and Cable retractor (task 2)

The micro ROV is a round cylinder. This avoids having sharp edges. The body is separated into 5 parts. In case one of them is broken, it can be easily replaced. The micro ROV bodies have 6 assistance wheels which help the micro ROV to move forward inside the tunnel. The micro ROV is made with 3D printed material (PLA plastic). There are two thrusters and one camera with a light embedded. Our power is transferred from the surface through the main ROV tether and control switches to the ROV.

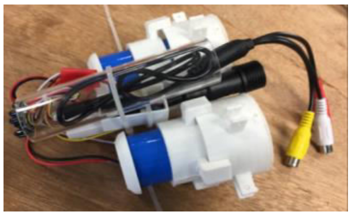


Fig3.17f Mini-ROV

In the protection and transfer portion, the cable is uses a UTP cable which has a plastic cover on it. The thrusters are also protected by a cover that meets the rule requirements. In terms of waterproofing the part, the thruster and camera were waterproofed via a glue seal and epoxy.

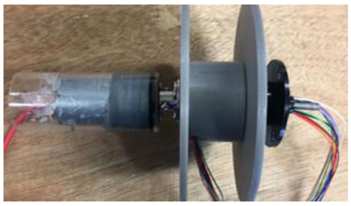


Fig3.17g Cable retractor

In the electrical part, the ROV is fused by a 5A fuse. The cable length is 4 meters. There are 2 signal cables and 6 power cables which all carry 12V. The signal cable is copper connected by copper wire. In the cable retractor part, the device is controlled by the surface control box which is connected to the motor. The cables retractor is designed to help the micro ROV back to the main ROV from the pipe. It can help the micro ROV dock inside the ROV quickly. The motor is also waterproofed to avoid electric shock. The camera is also waterproofed to avoid damage or malfunction. A separated 9-inch LCD monitor is connected to the camera so as to display real time images captured by the camera.

F) Trout fry transporter (task 1)

The transporter is responsible for transporting and releasing trout fry to the new habitat safely. The transporter is recycled material. It is the top and bottom of a beverage carton. It consists of two parts: two caps and a rubber band. It is attached to the gripper and is removable. When the gripper is opened, the trout fry being held inside the transporter are released.

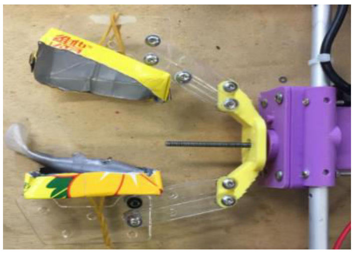


Fig 3.17h Trout fry transporter

G) Automatic image recognition system (task 2)

To accomplish this task, we have designed a program to recognize different shapes from the image received from the ROV's camera using Python and OpenCV. The recognition process is done by detecting the number of sides of a shape. To reduce the chance of an inaccurate detection, we have also set up limitations on the size of the shapes that are needed to be recognized. The advantage of using this program is its processing speed and high precision in determining different shapes. We will send the image captured by the ROV's camera to the program in the notebook computer. The image recognition program will then process the recognition in real time.

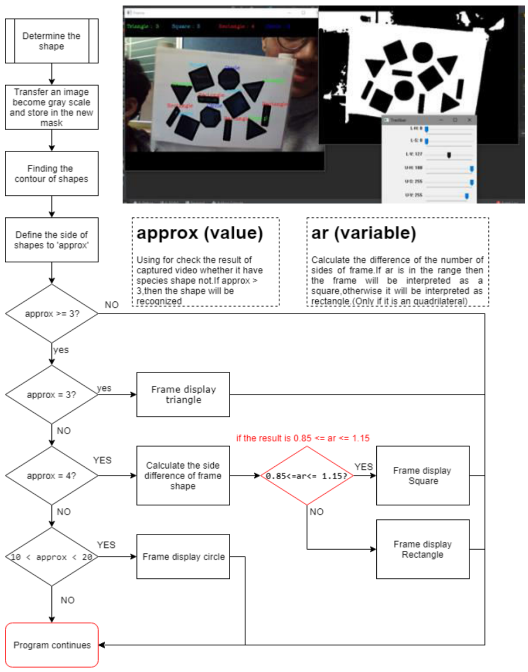


Fig 3.17i Program Flowchart

C. System Integration Diagram

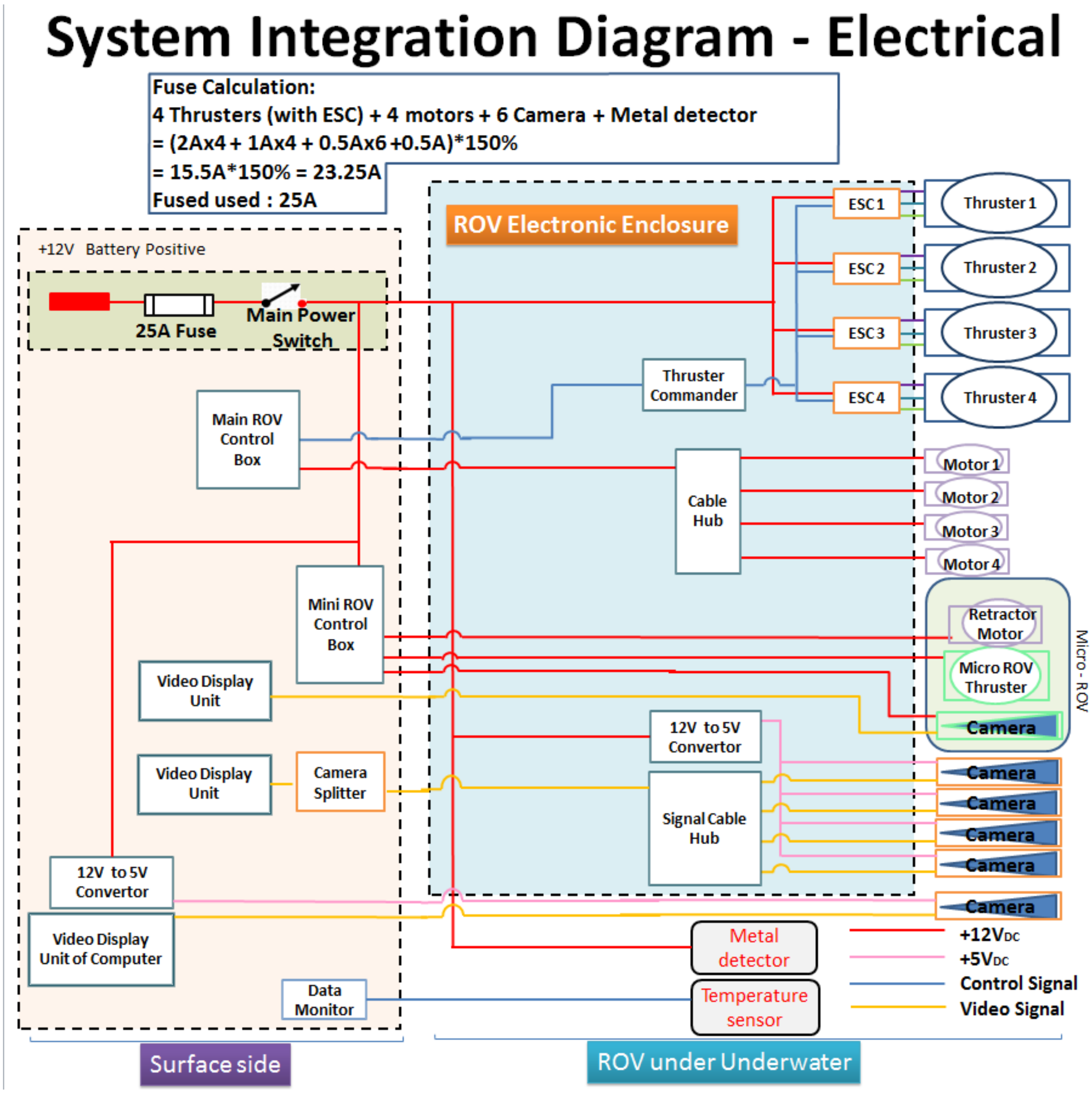


Fig 3.18 SID of the Main ROV system

D. 3D Design Software (Fusion 360 and TinkerCad)

Autodesk Fusion 360 Education License is used to design different components of the ROV. The software helped us to design parts more efficiently and accurately by providing the actual distance. The 3D design software helped us design the ROV framework joints, thruster protect cover, the rotatable payload, rotating Helix device, releasing nut of the dropper and attached parts of the camera. It reduced the time it took for the crew to build various parts of the ROV.

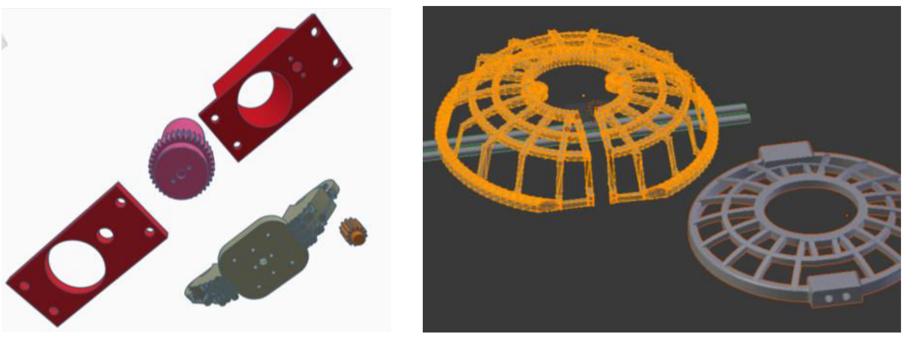


Fig 3.19 Use of 3D design software (captured by: Melody)

Prototype design

We used the 3D design software to sketch out the design of the ROV structure and all components which can be mounted to the ROV. By creating a simulation of the ROV and prototyping our design, we improved the positioning of the major components which increases the safety and performance of the ROV.

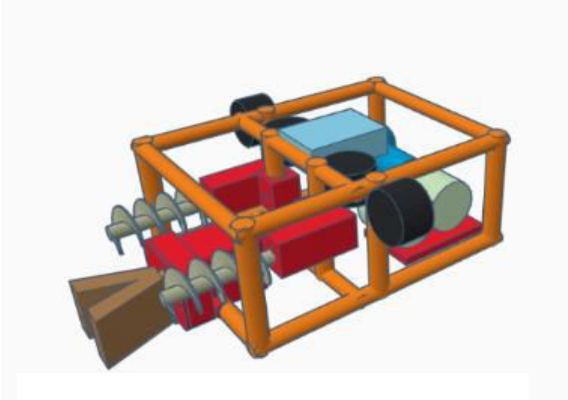


Fig 3.20 Prototype design of ROV

IV. Build Vs buy, New Vs Used

In discussing the "build or buy" issue, the principle of our team is that we build as much as possible. To purchase a complete tool from the market would cost much more and detract from our fun, even though it is time saved. We deeply believe that through the process of designing and building, we can learn more about the mechanisms of the product, appreciate more about the product in the marketplace and most importantly, we can evaluate the ready-made market product. After the evaluation of both the ready-made products and our craftsmanship skills, we made our decision.

The following items are too expensive to purchase from market.

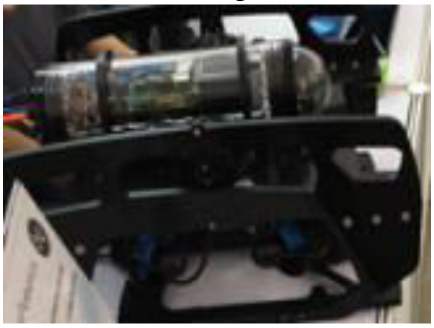


Fig 4.1 ROV body

Fig 4.2 Pay Load (Gripper)

Fig 4.3 Water proofed camera

Here are tables comparing the commercial products and self-made tools. ROV. KWOK TAK SENG INC. found that the commercial products were generally more expensive than homemade. The design of commercial product requires further modification before being adapted for KTS-Dolphin use. Therefore, our company decided to self-make the gripper and camera for our ROV.

Pay load (Gripper)	Ready-made product	Self-made
Cost($)	HK$ 3200	HK$100
Time use(days)	About 10 days(including shipping)	About 20
Modification difficulties	High	Low
Maintainability	Low	High

Water proofed camera	Ready-made product	Self-made
Cost($)	$350	$60
Time use(days)	About 10	About 5
Modification difficulties	High	Low

Maintainability	Low	High

As for the thrusters, camera and ESC (electronic speed controller), it was too difficult for high school students to build them. The self-made thruster performance was below our expectations. The thrust power was not high enough. Also, the price of building a thruster from raw material was higher than commercial price. After researching the commercial product in the marketplace, KWOK TAK SENG INC. found that the Blue-motor T100 had high efficiency power and was most suitable for our ROV. In conclusion, we purchased these items commercially.

As for the body and the gripper of the ROV, we drew a 3D graph ourselves. We custom made the part to fit in the ROV and it was more suitable for us to create and design the ROV this way. Modifying it part by part, we built some components that could not be found in the marketplace. It is also easier for downsizing as this provides a higher performance. In addition, we also found two re-used items: a metal detector and temperature sensor from previous years. They are suitable for us to use this year.

V. Safety

Safety always has the highest priority in every domain of work. As the team values the safety of every member, we have developed a safety checklist to minimize the possibility of accidents (see report p.25).

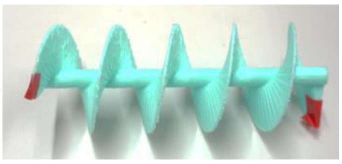
Safety precautions

For safety in the workshop, we always check our own appearance to make sure safety precautions were taken. We make sure our shoes are neatly tied, as well as having safety glasses constantly worn. We keep our desk clean and tidy, clean up spills and rubbish so as to prevent accidents, such as tripping over wires or tools and accidental fires. Stumbling on twisted wires or overloading of circuits should never occur. Therefore, wires are placed neatly and not exposed. We have even divided our workplace into sections allowing us to concentrate on our work, while disturbing others less and at the same time, lowering the risk of injury. In addition, extra care is needed while handling corrosive fluid or high temperature objects such as epoxy, chloroform etc. When handling dangerous and toxic chemicals, members are required to wear gloves and masks so as not to breathe in toxic substances or irritate their skin. Glasses are worn during soldering to prevent burns. Before leaving the workshop, we always check to be sure the dangerous tools, such as scroll saw, drill bed, heat guns, etc. have all been completely switched off and returned to their respective positions.

Safety feature of ROV

- Propeller is sheltered by a plastic case and covered by red warning tape to indicate danger. This prevents people from putting their fingers or other body parts into the motor and causing injury. Most of the corners are round, while sharp edges are either protected by plastic tubing, plastic adhesive tape or have been rubbed off.
- Accessories are waterproofed inside the waterproof boxes.
- Fuses are used to protect the circuit and the same goes for the output devices.
- Plugs are kept away from water source and dry to prevent electric shock.
- Strain reliefs are added for resisting the tension on the cable when it is stretched so that the chances of cables disconnecting is reduced, and electric shock is avoided during operation.

The following table (Table 5.1) shows some of our adoptive safety measures:

 Use of Anderson power plug	 In line 25A fuse within 30cm	 Sharp edges are painted red	 Use of Key switch
 Thrusters are shrouded and guarded	 Use of strain relief	 100% passed the fluid quiz	 Fuse on Non-ROV device

Great Lakes	Neptune Engineering	Marlette High School	Paula McElroy	PASS
Hong Kong IEEE	CMAss Robotics Team	CMA Secondary School	Suet Yee Queenie, Yeung	PASS
	CMA Underwater Expert Ltd.	CMASS	Suet Yee Queenie, Yeung	PASS
	Smart team	Cotton Spinners Association Secondary School	Mr Lau Ming Hang	PASS
	Ching Kok	HHCKLA Buddhist Ching Kok Secondary School	Ng Chak Man Victor	PASS
	BLANK	HKUST	Eric	PASS
	KTS-Dolphin	Kwok Tak Seng Catholic Secondary School	Lee Siu Fung	PASS

VI. Challenges and Trouble Shooting Techniques

Making a ROV is very challenging as it requires creativity, knowledge and cautiousness. While we were building KTS-Dolphin, we have encountered many difficulties.

6.1 Technical challenges

A) T100 thruster draws too much current

Using T100 thrusters in 12V draws too much current from the main power supply when changing rotating direction, which affected other electronics like the camera. The current supply to the camera was not been steady.

Solution: We solved it by adding a voltage regulator and capacitor to the camera which stabilized the voltage to the camera and ensured a clear image from it. We also changed to the T200 thruster which draws less current from the power supply.

B) Signal delay between two Arduino processors

We used two Arduino microprocessor boards connected with the RS485 to send control signals to control the movement of the thruster. The design was good, but it had a major disadvantage. The delay of the signal to turn the ROV became very difficult. Thruster signals also had to send other control signals. This led to signal jam in some cases.

Solution: We now use a thruster commander to control the ESC directly by joystick with a potentiometer in this year. The joystick contains two 10K resistance. It can send out different levels of potential difference which act as signals to control the ESC directly. This results in almost no delay.

C) Hard to find the center of gravity

We had plenty of devices that were attached to the ROV. In the first water trail test, our ROV raked forward in water since we didn't know the center of gravity of our ROV. However, we tried numerous tests and changed the position of thruster on the framework to ensure the ROV could balance in water. It was time consuming to find the right position and the limitations of our design.

Solution: We designed a new frame which was formed by aluminum pipes and a 3D-print movable connecter which was connected with the thruster. It can change the position of thruster easily and regulate the center of gravity to help ROV move smoothly.

D) Camera interference

Our camera showed a distorted image. If all the devices were functioning properly, the images of the four cameras should be clearly displayed on the LED display monitor. When we were testing our four cameras, the image was blurred and wavy. We replaced one of the cameras and a clearer image was shown. This suggested that the signals of each camera had interfered with each other and lowered the quality of images.

Solution: To tackle the above problem, we try to connect the cameras one by one, to find out which cameras were interfering with the other. However, through several experiments, we found that the image quality problem was caused by grounding them together. We now have successfully solved the interference problem by grounding the cameras separately. The quality of image displayed has significantly improved.

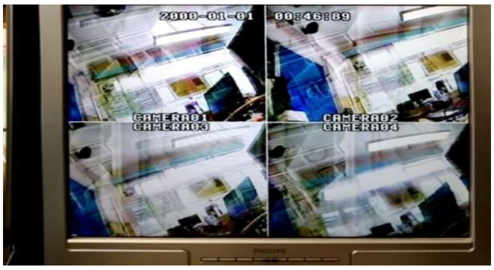


Fig 6.1a Image display before enhancement

Fig 6.1b Image display after enhancement

6.2 Non-technical challenges

E) Time Management

We encountered a lot of non-technical challenges. Because the date of competition is near our examination, we had trouble managing out time.

Solution: We have a strong team spirit and every teammate is very responsible. During the examination, form 6 members, who have already finished their public examinations, helped move the project along. After the examination, all members were back to the previous work schedule.

F) Lack of experience

Half of the team members are new to this competition. Our new members found it difficult to finish their parts by themselves. So, the degree of progress was not the same in every area and some parts had difficulties catching up.

Solution: Fortunately, our teammates are always willing to help each other by sharing their experience with newer members. We worked in pairs, with the senior members guiding the junior members. We also have regular meetings at lunchtime when we discuss the progress any troubles we are facing, so as to find the solutions together.

VII. Lesson Learned

7.1) Technical skills

We learned lessons about waterproofing, connecting different electronic parts, and designing the 3D model to use 3D printing. This is the first year we have used 3D models for creating and building our ROV. It was difficult to correctly size different parts. We needed to measure the gap and modify the graph in Fusion 360, which taught us how to draw a 3D graph and modify the graph. We also used a new system from BLUE ROBOTICS to control the ROV, so we needed to figure out how we could connect different parts with the system, so as to allow all the parts to become functional. In conclusion, we gained skills in waterproofing, connecting electronic parts and 3D modeling.

7.2) Interpersonal skills

As a new team, many of us did not have much experience making ROVs. At first, each of us was just working independently and we did not communicate with each other much. Because of this, when we ran into difficulties, we often got stuck and wasted so much time figuring out the solution alone instead of bringing our issue up to the group. But after some talks with our advisor, we began to understand the importance of communication between members, especially when facing problems that could not be solved alone. We started to have discussions during our lunch breaks to talk about our progress and any problems we were having. Giving and asking for suggestions from one another, we could see things from a different perspective and come up with new and improved ideas. Along with the regular meetings, we learnt to give suggestions and manage our progress. We benefitted greatly from this newfound management skill and our team is now the most efficient it has ever been.

VIII. Further improvement

8.1) Reduce Water Resistance

Currently, a brick-shape control box is used to centralize and waterproof all the electrical components inside the ROV, which leads to high resistance under water during the operation. This causes the movement of the ROV under water to be slow and jerky, especially when turning. This also causes target positions to be misread on missions. In order to cope with the problems that we have mentioned above, water resistance needs to be reduced. When making a control box for the ROV, we need it to be a streamlined-shape such as adding a 3D-Printed streamline cover so that there is less fluid drag and resistance under water.

8.2) Errors in Designing

During the design process, we often found errors in our design and made numerous changes and large areas needed to be reconstructed. Time was wasted on repeated work. We should have expected difficulties of design before construction. If those difficulties could have been solved, we could have started implementing the design earlier. Also, we should have scratched a diagram of the component design. Moreover, prototypes should have been made in order to try out the design. That way we could check whether the size was suitable and fit. For example, using some cardboard to cut out the outline of the design of our gripper head.

8.3) Distribution of Workload

As many components of the ROV were made from 3D printing, the workload of our 3D designers was heavy. The reason why all the design work is a burden for only one or two members is that most of us are not skilled in using 3D design software. If more members learn to draw 3D graphics using software like Fusion 360, the workload could be shared and speed up future design processes.

IX. Reflection

- **Tam Ching Yuen-** Even though this is my second time joining the ROV competition, I have never been the CEO before. I needed to hold meetings and monitor the whole process of the project. It was difficult for a team with little experience to build an ROV and many troubles were found along the way. But I am glad that we all worked together as a team and solved the problems one by one. I am proud to lead such a spontaneous and united team.
- **Lo Wai Nam-** After making this ROV, I have learnt many things along the way, such as soldering, drawing SID, etc. Making an ROV has also improved my communication skills because there were lots of moments I needed to cooperate with my teammates and share ideas during meetings. In conclusion, I would like to join the competition again next year.
- **Chan Hong Sui-** I am responsible for the software of the ROV. One challenge for me was the development of the automatic image recognition system as it involves the application of Python and OpenCV. These programming languages were entirely new to me. Despite having previous knowledge about C programming language, I still found it difficult to master the program. After searching the Internet for a bunch of information and various algorithms testing, I have finally mastered these programs and broadened my programming knowledge at the same time.
- **Sit Yan Tung-** This is my first time participating in the ROV competition. Out of all the members, I am the youngest, but I was assigned an important role—being the designer of ROV payload! Lacking mechanical knowledge, I found it really hard to accomplish this task. Luckily, I was guided by senior teammates. We designed and collaborated together and were eventually able to finish making the gripper. I was really impressed by the process by which gears, motors and other materials are connected together and in the end, can work so smoothly together.

X. Team Work

We did a lot of research and asked for training from our team advisor. By learning from the previous work of our graduates, we had the basic knowledge of constructing a ROV and resources available. We study the mission and the requirements details together. Then we brainstormed ideas about how to accomplish the tasks. Members are assigned job according to their talents. For example, 3D designing was drawn by members who are familiar with 3D designing software, while electronic work was conducted by members who study physics. For the report and other documents, the report team was responsible for writing them, but everyone was involved with the content (refer to p.25 / appendix). Each member wrote the content of their responsible part of the ROV and the report team helped proofread. There were numerous times when we were frustrated along the way, but we encouraged each other. When we met difficulties, we would discuss all possibilities and solve them as a team. This also helped us to maintain the progress of the project as we all knew how each part was progressing. Besides sharing our problems with the team, we looked for suggestions from our previous members because they are more experienced in building an ROV. Moreover, we often hang out and have meals together, so as to strengthen the team spirit and better cooperation.

Fig 10.1 Cooperation of teams in making ROV

Fig 10.2 Team work all the time

XI. Project Management:

To accomplish all the requests from the Eastman Company was not an easy job. Hence, good management skills had to be applied to each individual or group works of the project. In order to manage the project well, four departments were formed. They are **Hardware ROV, Mechanics, Electronics** and **Software**, and the Safety department. The four department heads were selected by the students and each head supervises their team members. Regular weekly meetings were conducted to reporting all progress to the CEO and project advisor. During meetings, a logbook was kept and updated. We also discussed problems that we were facing, and different solutions were evaluated and justified.

The schedule of work was refined according to different situations if, and only if, the issue had been thoroughly discussed first. Each department head recorded the work done in the logbook which was inspected by the CEO and team advisor to ensure all the teams could achieve the specific goal, according to their goal descriptions, on schedule. This ensured that the process of planning, organizing, motivating, and controlling resources, procedures, and protocols to achieve specific goals proceeded on schedule. The CEO and financial Sectary also controlled the budget we planned and used.

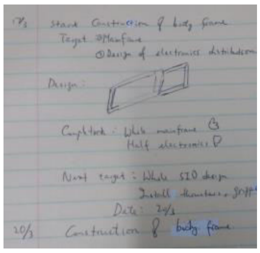


Fig 11.1 Log book

Schedule of works

	Event	2018						2019											
		Sept		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun	
1	Evaluation of last year competition and Fund Raising	■	■																
2	Learned the mission and research the information			■	■											■			
3	Discuss the idea of solving the task and planning the post of each member			■	■											■			
4	Study the feasibility for whole system				■	■										■			
5	Comparing & Discuss different designs				■	■										■			
6	Finalize the Design					■										■			
7	Hardware Purchases (Thrusters, ESC, Thruster Commander, Camera, motors, Aluminum pipe, etc)						■	■								■	■		
8	Design, implementation and unit test:							■	■	■	■	■	■			■	■		
	a) Building framework b) Thruster Assemble Integration with ESC c) Connection And Testing thruster Commander and Integration of Cables Into The Main Control Box d) Design Payload With Rotating Arm e) Making Water Proofed Camera f) Waterproofed Electronic Components And Plugs g) Micro-ROV, Releasing Grout Device, h) Helix Dropper, Tires Grabber, Trout Fry Transporter i) Automatic Image Recognition System							■	■	■	■	■	■			■	■	■	
9	System integration and testing										■	■					■	■	
10	ROV Waterproofed test									■	■	■	■				■	■	
12	Documentation (Writing Report, JSA, etc)													■		■	■		
13	Hong Kong Regional of MATE ROV Competition														■				
14	MATE ROV International Competition																		■

XII. Budget Sheet

Budget

School Name: Kwok Tak Seng Catholic Secondary School (K-Dolphin)
Instructor/Sponsor: MR. LEE SIU FUNG

From: 9/1/2018
To: 5/20/2019

Income	Source	Amount (US)
	School's Grant	$ 1,519
	Students' Donations	$ 63
	Parents' Donations	$ 63
	Kwok's Foundation Sponsor	$ 25,316

Expenses

Category	Type	Description	Projected Cost	Budgeted Value
Registration free	Purchased	Registration free	$ 329	$ 329
Registration free	Purchased	Registration free	$ 137	$ 137
Hardware	Purchased	4 x Thruster (T100)	$ 603	$ 603
Hardware	Purchased	7 x motors	$ 32	$ 32
Electronics	Purchased	5 x Camera	$ 51	$ 51
Electronics	Purchased	4 x Electric Speed Control	$ 127	$ 127
Electronics	Purchased	2 x Thruster commander	$ 127	$ 127
Electronics	Purchased	Joystrick, switches, buttons	$ 25	$ 25
Hardware	Purchased	General machanical parts	$ 190	$ 190
Electronics	Purchased	Google Voic kit with camera	$ 114	$ 114
Sensors	Reuse	Temperature Sensors	$ (16)	$ 16
Sensors	Reuse	Metal Detector	$ (32)	$ 32
Hardware	Reuse	Monitor	$ (253)	$ 253
Hardware	Reuse	Video splitter	$ (51)	$ 51
International competition	Travel Expense	Air Ticket (round trip) to USA	$ 21,392	$ 21,392
International competition	Travel Expense	Hotel Accommodation	$ 1,810	$ 1,810
International competition	Travel Expense	Local Transportation	$ 405	$ 405
International competition	General Expense	Including food, uniform, allowance for student	$ 1,266	$ 1,266

Items must fall into ont of the following:
Purchased - defined as items that are purchased new or service paid for.
Re-used - defined as items that were purchased in previous years. Amount listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to you company. School for general use excluded.
Cash donated - defined as funds contributed to your company. Do not include funds given to your school for general use.

Total Income	$ 26,961
Total Expenses	$ 26,960
Total Expenses - Re-use/Donations:	$ 26,608
Total Fundraising Needed/**Surplus**:	$ 353

PROJECT COSTING

School Name: Kwok Tak Seng Catholic Secondary School (K-Dolphin)
Instructor/Sponsor: Lee Siu Fung

Reporting period
From: 9/1/2018
To: 5/20/2019

(US$)

Date	Type*	Category	Expense	Description	Sources/Notes	Amount	Running Balance
10/1/2018	Cash donated	General		Funds donated by School	Used for general vehicle construction	$ 1,646	$ 1,646
5/20/2019	Cash donated	Trip to USA		Kwok's Foundation	Expenses for the international competition	$ 25,316	$ 26,962
2/15/2019	Purchased	Registration free	Registration free	Local ROV Competition - HK	for registration free	$ (329)	$ 26,633
2/19/2019	Purchased	Registration free	Registration free	Active MATE TECH & fuild quiz	for registration free	$ (235)	$ 26,398
3/2/2019	Purchased	Hardware	4 x Thruster (T100)	Blue robotics	for upward and downward movement of vehicl	$ (603)	$ 25,795
12/1/2018	Purchased	Hardware	2 x small size Motors	High gear ratio motor	for rotating pay load	$ (6)	$ 25,789
12/1/2018	Purchased	Hardware	5 x Motors	High gear ratio motor	for Mini-ROV, releasing objects	$ (25)	$ 25,764
2/18/2019	Purchased	Electronics	5 x Camera	Provide vision for ROV	for vision system of ROV	$ (51)	$ 25,713
3/2/2019	Purchased	Electronics	4 x Electric Speed Control	For controlling the Brushless thusters	for vehicle system	$ (127)	$ 25,586
12/1/2018	Purchased	Electronics	2 x Thruster commander	For controlling all thusters	for vehicle system	$ (124)	$ 25,462
12/1/2018	Purchased	Electronics	Joystrick, switches, buttons	controller of the entire system	for vehicle system	$ (25)	$ 25,437
2/18/2019	Purchased	Hardware	Aluminium pipe	Structure of the ROV framework	for ROV vehicle frame (Body)	$ (14)	$ 25,423
2/19/2019	Purchased	Consumables	3D Filament	3D printed control box	for ROV vehicle frame (Body)	$ (32)	$ 25,391
12/1/2018	Purchased	Hardware	2 x Water-proofed Boxes	For electronics on the ROV	for ROV vehicle frame (Body)	$ (18)	$ 25,373
12/1/2018	Purchased	Consumables	Acyclic board	Material for building various part of ROV	for ROV, tools	$ (13)	$ 25,360
1/9/2019	Purchased	Consumables	Various size of Screws	for fixing various components	for system integration	$ (13)	$ 25,347
3/10/2019	Purchased	Hardware	Electrical cable , UTP	provide connection for various component	for system integration	$ (63)	$ 25,284
3/14/2019	Purchased	Hardware	Waterproof electrical connectors	wire connector	for system integration	$ (15)	$ 25,269
3/14/2019	Purchased	Electronics	Ansderson Switch	wire connector	for system integration	$ (5)	$ 25,264
3/17/2019	Purchased	Electronics	25A Fuse	Fuse	for electric current protection	$ (3)	$ 25,261
3/17/2019	Purchased	Electronics	Google Voic kit with camera	for image recognition	for accomplish task	$ 114	$ 25,261
9/1/2018	Re-used	Sensors	Temperature Sensors	Measure water temperature	for accomplish task	$ 16	$ 25,261
9/1/2018	Re-used	Sensors	Metal Detector	determination of metal	for accomplish task	$ 32	$ 25,261
9/1/2018	Re-used	Hardware	Monitor	Camera Vision	for ROV Version	$ 253	$ 25,261
9/1/2018	Re-used	Hardware	Video splitter	Camera Vision	for ROV Version	$ 51	$ 25,261
5/20/2019	Travel	Travel	International competition	Air Ticket (round trip) to USA	for transportation	$ (21,392)	$ 3,869
5/20/2019	Travel	Travel	International competition	Hotel Accommodation	for accommodation	$ (1,810)	$ 2,059
5/20/2019	Travel	Travel	International competition	Local Transportation	for transportation	$ (405)	$ 1,654
5/20/2019	Travel	Travel	International competition	General Expense	Including food, uniform, allowance for student	$ (1,266)	$ 388
						Total Raised	$ 26,962
						Total Spent	$ (26,574)
						Final Balance	$ 388

***Items must fall into one of the following:**
Purchased - defined as items that are purchased new or services paid for.
Re-used - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to your company. Do NOT include items given to your school for general use.
Cash donated - defined as funds contributed to your company. Do NOT include funds given to your school for general use.

XIII. Acknowledgement

MATE Marine Advanced Technology Education Center	Marine Advanced Technology Education Centre – Competition organizer
IET The Institution of Engineering and Technology HONG KONG 25 YEARS	IET Hong Kong Branch – Regional Competition organizer
新鴻基地產 Sun Hung Kai Properties 郭氏基金	Sun Hung Kai Properties Kwoks' Foundation Limited – Sponsor of travel expenses to USA
天主教郭得勝中學 Kwok Tak Seng C	Kwok Tak Seng Catholic Secondary School
Praise Technology Limited MAKER WISE movehand.com	SMC SMC— pneumatics sponsor

XIV. Reference

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XV. Appendix **Printed on request**

I) Safety Checklist Form

I) Safety Checklist Form

Safety of checklist is compiled by mechanical engineering and Electrical engineering and manager.

Safety checklist items	☑	Double check / Remarks
Pilots and ROV tether controllers at all times:		
1. All people wears accurately tied or closed toed shoes.	❑	❑
2. All people wears safety glasses	❑	❑
Before the ROV deport to the water: (Mechanical inspection)		
1. All components and cables are attached firmly	❑	❑
2. All danger parts are identified and protected	❑	❑
3. All danger parts are identified and labeled as danger	❑	❑
4. Sharp edges are rounded off.	❑	❑
5. Propellers are attached securely and with protection shield.	❑	❑
6. Tether and waterproof plug neatly coiled	❑	❑
7. Motors function properly.	❑	❑
8. Camera is focused and securely attached.	❑	❑
9. No exposed thruster are found	❑	❑
10. All wires and devices for controlling on the surface of the water are securely attached in a control box.	❑	❑
Before the ROV deport to the water: (Electrical inspection)		
1. 25A fuse is presented in the control unit and in good condition	❑	❑
2. 25A Fuse is attached within 30cm from the power supply	❑	❑
3. Check the connection of main power supply	❑	❑
4. All Plugs are dry and secure attached.	❑	❑
5. Unused plugs should also be shielded	❑	❑
6. All connection are labelled	❑	❑
7. No wires are exposed / No open end wire.	❑	❑
8. Ensure the input voltage matches the expected	❑	❑
9. Checking of RS485 communication signal	❑	❑
10. Check Pressure reading	❑	❑
Overall System Checklist		
1. Ensure all thrusters function properly (UP,DOWN,LEFT,RIGHT)	❑	❑
2. Payload function properly (Open, Close)	❑	❑
3. Checking the normal function of air compressor and tubing are securely attached.	❑	❑

Sign of the first Staff:	
Name of the staff:	
Date and Time:	
Sign of the Second Staff:	
Name of the staff:	
Date and Time:	

II) Team work of Technical Report

Departments

Department	Department Head / CEO	Department Members
CEO	Tam Ching Yuen Wong King Ho	N/A
Hardware ROV	Wong King Ho	Lo Wai Nam Kwok Tsz Him
Mechanics	Ng Hoi Ming	Fung Ching Yiu
Electronics and Software	Chan Hong Sui	Sit Yan Tung Lo Wai Nam
Safety	Pong Hei Chung	Tam Ching Yuen Du Chun Hin

Team work of Technical Report

Technical Report Contents	Person-in-charge
Abstract	Tam Ching Yuen
I. Photo of ROV	Du Chun Hin, Pong Hei Chung
II. Design Rationale	Wong King Ho, Kwok Tsz Him, Lo Wai Nam
III. Vehicle Core System	Wong King Ho, Du Chun Hin
A. Mechanical	Ng Hoi Ming, Pong Hei Chung, Wong King Ho
B. Electronics	Lo Wai Nam, Chan Hong Sui, Wong King Ho
C. System Integration Diagram	Lo Wai Nam, Du Chun Hin
D. 3D Design Software	Sit Yan Tung, Lo Wai Nam, Kwok Tsz Him
IV. Build Vs buy, New Vs Used	Chan Hong Sui, Wong King Ho
V. Safety	Tam Ching Yuen, Pong Hei Chung
VI. Challenges and Trouble Shooting	All members
VII. Lesson Learned	All members
VIII. Further improvement	All members
IX. Reflection	All members
X. Team Work	Kwok Tsz Him
XI. Project Management:	Tam Ching Yuen, Du Chun Hin
XII. Budget Sheet	Du Chun Hin
XIII.Acknowledgement	Du Chun Hin, Pong Hei Chung
XIV.Reference	Du Chun Hin