2017 MATE International ROV Competition

(HONG KONG) - Technical Documentation

Company Name: **Kwok Tak Seng Inc.**

Team Name: **KTSCSS Dolphin**

School: **Kwok Tak Seng Catholic Secondary School**

City: **Hong Kong, China**

Team Adviser: **Mr. Lee Siu Fung**
Mr. Hon Sze Ping Steven

Our team photo

(From Left) Chan On Shan, Chan Sze Ting, Leung Yuet Ming, Ngan Wai Sing, Wong King Ho, Ng Kai Hei, Lee Kin Yuen Cyrus

Abstract

Upon the request of the Port of Long Beach for proposals of a remotely-operated vehicle and crew that can operate in confined and often precarious conditions of the port and waterfront, we carefully design our ROV for the proposal.

The mission consists of four major categories which are Commerce, Entertainment, Health and Safety. Our ROV is capable of tackling a variety of tasks including installation of **Hyperloop Construction**, replacement of the fountain (**Light and Water Show Maintenance**), determination of contaminated sediments (**Environmental Cleanup**), and locating and measuring the distance of cargo containers (**Risk Mitigation**).

It is controlled by a PS4 game pad. All equipment is assisted by a well-designed electrical communication system and has been tested under water. Our ROV is equipped with:

1) Six powerful brushless thrusters, for forward-backward, left-right turn movements, left-right shift adjustments and sink-rise motion,
2) Multiple cameras were made to give driver various view simultaneously for identifying and determination,
3) A pair of pliers (pay load) pneumatic system for grabbing and transporting objects firmly likes pins, rods, U-bolt , power cable and etc.,
4) A rotational arm for turning of the valve,
5) A sucker for collecting a sediment sample (agar) from the contaminated area, and
6) LED lights which simulate the detection and the activation of RFID for identification of the high-risk cargo containers.

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

(247 words)

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I. Project Costing

PROJECT COSTING

School Name: Kwok Tak Seng Catholic Secondary School
Instructor/Sponsor: MR. LEE SIU FUNG

From: 9/1/2015
To: 5/1/2016

Date	Expense	Description	Notes	Amount(US)	Balance
12/1/2013	General	School's Donation		$ 1,630.0	1,630.00
1/1/2014	General	Students' Donations		$ 35.0	1,665.00
2/1/2014	General	Parents' Donations		$ 60.0	1,725.00
2/1/2014	General	Teachers' Donations		$ 60.0	1,785.00
12/1/2015	Entry fees			$ (125.0)	1,660.00
9/15/2015	2 x Blue brushless motors	up and down thrusters	for upward and downward movement of vehicle systen	$ (125.0)	1,535.00
9/5/2015	2x Brushless thruster	Forward and backward thrusters	for forward and backward movement of vehicle system	$ (1,250.0)	285.00
2/22/2016	2 x Camera	Provide vision for ROV	for vision system of ROV	$ (20.0)	265.00
2/1/2016	4 x Electric Speed Control	For controlling the Brushless thusters	for vehicle system	$ (60.0)	205.00
2/1/2016	1 x H-birdge Motor controller	For controlling the up and down thusters	for vehicle system	$ (7.5)	197.50
12/10/2015	2 x Arduino mega 2560	Main circuit board of the ROV and controller	for vehicle system	$ (56.0)	141.50
12/11/2015	Joystrick compatible to Arduino	controller of the entire system	for vehicle system	$ (15.0)	126.50
12/11/2015	Water proofed plastic box	control box	for vehicle system	$ (7.5)	119.00
1/1/2016	Acycilic cylinder	Water-proofed ROV body	for ROV vehicle frame (Body)	$ (12.5)	106.50
1/1/2016	Acyclic board	material for building various part of ROV	for piliers	$ (44.0)	62.50
3/12/2016	Various size of Screws	for fixing various components	for system integration	$ (10.0)	52.50
3/12/2016	Electrical cable	provide connection for various components	for system integration	$ (25.0)	27.50
3/12/2016	Waterproof electrical connector	wire connector	for system integration	$ (7.5)	20.00
3/12/2016	DINKLE ED350V-02P(green) Te	wire connector	for system integration	$ (5.0)	15.00
2/16/2016	Multi functional circuit board	for system circuit integration	for system circuit integration	$ (4.0)	11.00
2/16/2016	PVC pipe 2'	PVC pipe	for ROV vehicle frame (Body)	$ (5.0)	6.00
2/16/2016	A matallic plate	for supporting the ROV body	for ROV vehicle frame (Body)	$ (6.0)	0.00
12/1/2013	Pay Load	Gears	Re-used	$ 20.0	20.00
12/1/2013	Cable	18 AWG silver coated CU wire (100FT)	Re-used	$ 75.0	95.00
				Total Raised	$ 1,785.0
				Total Spent	$ (1,785.0)
				Final Balance	0

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. 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.

Reason of reusing items

There are lots of items that we reuse, like motors, the controller, and the Adriano mega board. One of the most important concerns of reusing these items is to reduce the budget. Our budget is highly limited this year. Everything of our ROV has to be well-designed to fit our budgets. In facts, we reduce 40% of spence this year. In addition, the budget is not only points we concern to reuse items but also the reliability of the components, the efficiency of making new components and whether the components still fit our new design. For example, the motor for rotating arm still fits our new design of the pliers and it still working well. Therefore we design to reuse it. And also for the Arduino mega board is reused for the same reason. All reused items are tested to ensure it can still function properly.

II. System Integration Diagram

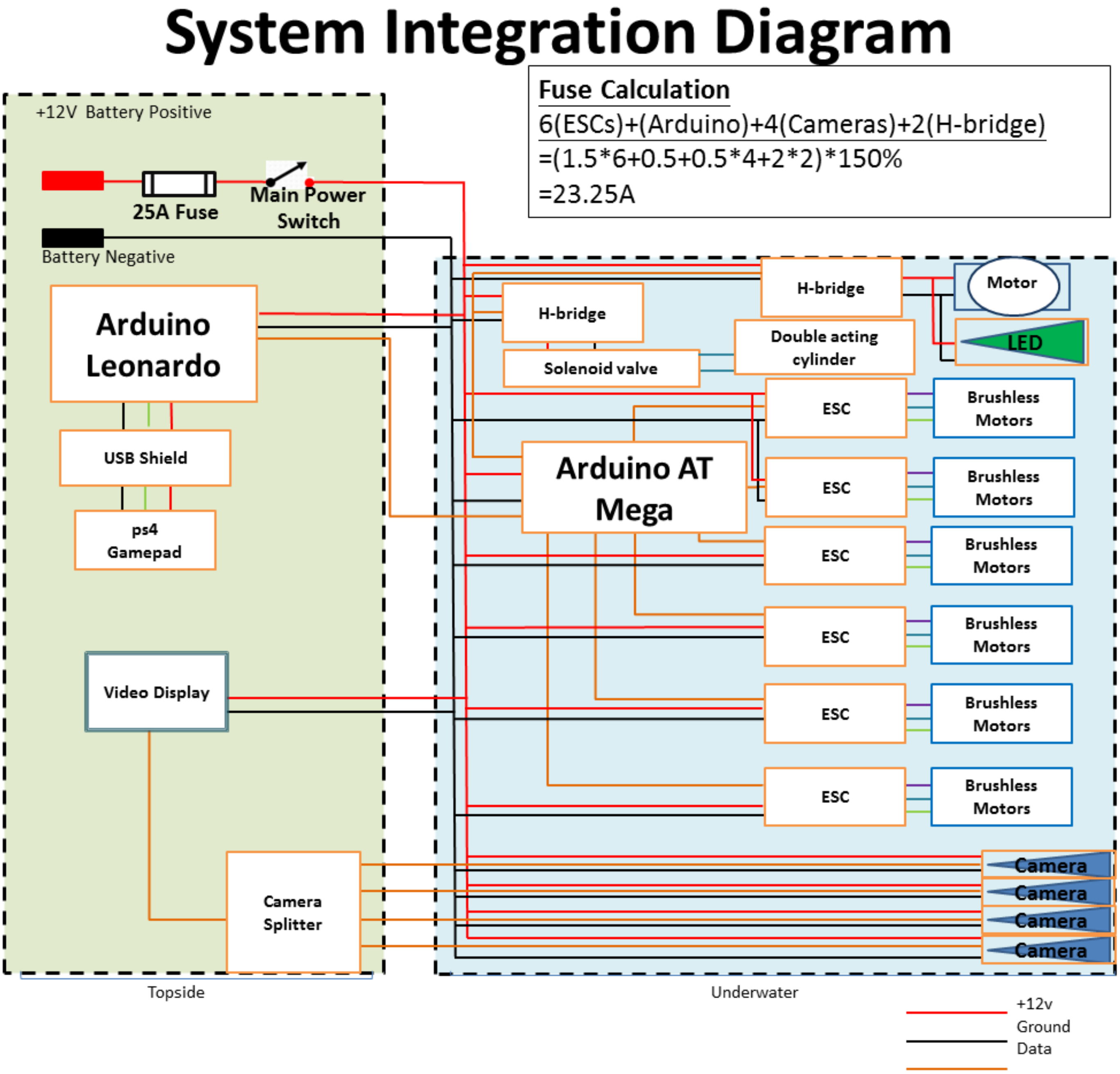


Figure 1 SID

III. Design Rationale

Most of the components of our ROV are newly designed and constructed. They consist of an external framework made by an aluminum strip as the ROV's main body, a cylindrical camera chamber, six water proofed thrusters as the vehicle system, a pneumatic payload (a pair of pliers), a rotational arm and a sucker for collecting a sediment sample (agar) from the contaminated area. The major concern of the design rationale is that the movement of ROV under water is too slow which affected by two factors. The first one is the water resistance. The other is the power of the thrusters. However, the above two 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 thrusters and the streamline design of the ROV are the two important design rationales to encounter the affections.

To build a highly efficient ROV underwater is our major objective, as we have only 15 minutes to complete all the tasks. From our experience in the previous years, using brushless motors is much more efficient than brushed motors. The efficiency and speed is greatly increased. As a result, two brushed motors responsible for vertical movement of the ROV are replaced by brushless thrusters. The cylindrical chamber is a streamline design to reduce the water resistance affections. The cylindrical chamber also provides a high up thrust force under water to provide a buoyant ROV.

For off-shore controlling, the control box is too bulky. To make it smaller with full functional buttons, an PS4 game pad with two multi-directional controls and 8 buttons are adopted for controlling all components of the ROV.

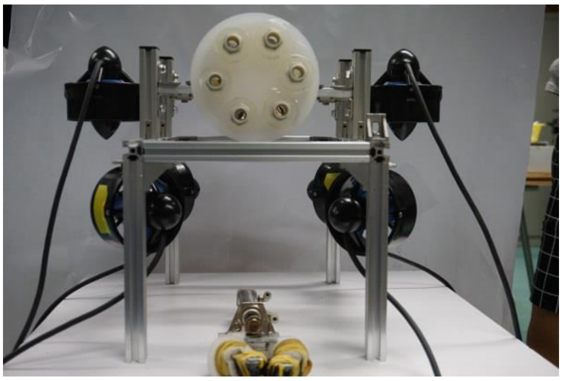


Figure 2 Font view of the ROV

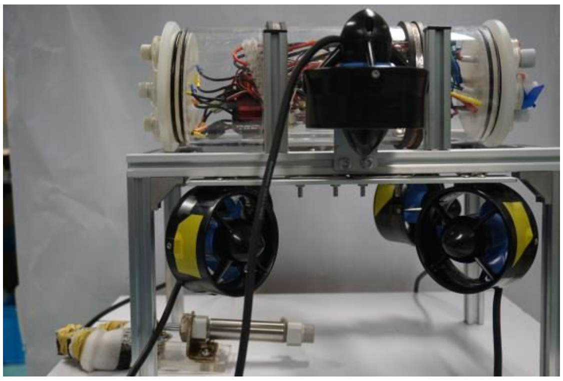


Figure 2 Side view of ROV

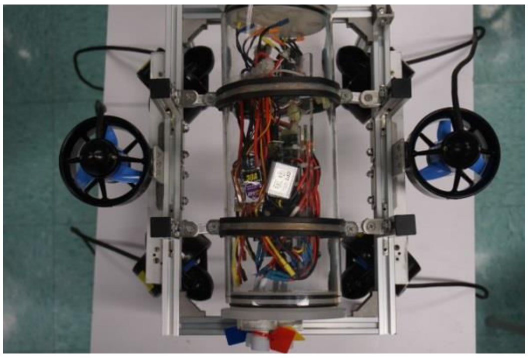


Figure 3 Top view of ROV

A. Framework and Buoyancy

The frame of our ROV consists of one water-proofed acrylic cylindrical chamber and some acrylic boards and aluminum strips. The acrylic cylindrical chamber is water-proofed by adding two O-rings and petroleum jelly between the surfaces of the acrylic plates. All components will be affixed with acrylic boards into the main body of the ROV. The ROV frame is specifically designed to acquire the following advantages.

First of all, the size of the ROV body frame is reduced to fix the requirement of the specification. Each of the cameras is sealed with epoxy and enclosed in an acrylic cylindrical tube. They are highly mobilized to fix any parts of the ROV. The tools can be attached to the exterior frame body more easily when compared to attaching the tools onto the curved surface of the acrylic cylinder. In addition, it is easier for us to attach and remove different tools to the ROV.

Last year, out camera and all electronic components were put together to minimize the size of the ROV. According to the evaluation of the previous year, the view camera was blurred by the water vapor contained in the air of the chamber. In this year, we redesigned the arrangement and the connection of camera chamber by separating it from the main body.

The main electronic components of our ROV are placed in the waterproofed chamber. This makes it easier to perform maintenance. The accessories, such as the pliers, are clutched to the main ROV body. This reduces the size of our ROV significantly in order to score 20 bonus points from the requirements which limited the size within 48 cm diameter.

In order to reduce the fluid resistance of water, we designed our ROV in a streamline shape and a small size. The center of gravity (CG)of the whole vehicle is on the middle of the vehicle, with the center of buoyancy (CB) above CG.

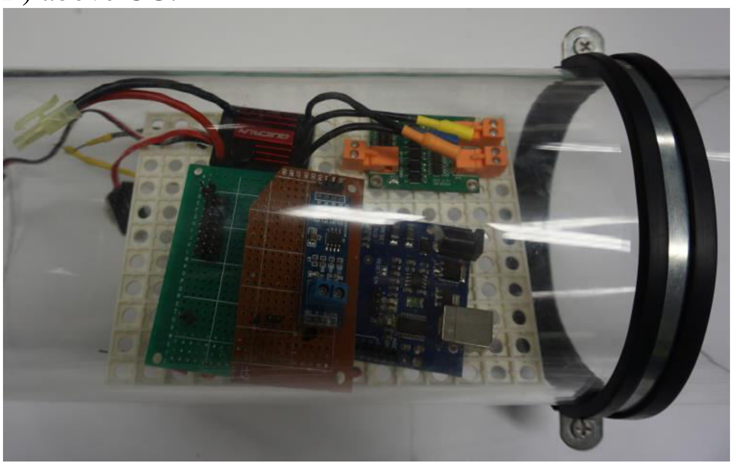


Figure 4 Waterproofed cylindrical chamber for storing all electronics

Moreover, since the waterproofed chamber stored the accessories like the Arduino AT mega board, the ESC and all electronic components, it is covered by tight screws with O-rings so that water cannot easily get inside the box. As the acrylic cylinder is also enclosed by two acrylic plates and two strong O-rings, water cannot easily get into the cylinder. But we are still worried that water may slowly leak into the cylinder. As for the cable connection holes in and out of the box, we sealed them with AB Proxy agent to make them water- proofed.

Both the waterproofed chamber provides a large up thrust force under water to provide buoyancy of the ROV to encounter the weight of the ROV. The diameter and the length of the acrylic cylindrical chamber have been measured carefully for providing a suitable up thrust to encounter the total weight or the ROV.

Besides, it is easier for us to attach tools including pay load to the frame body.

B. Vehicle System

1. Thrusters

The vehicle system of our ROV consists of six thrusters. The four T200 blue robotics thrusters are used to control the movement of the ROV in all directions including forward, backward, left-right turn and left-right shift movement. Another two blue robotics motors T200 thrusters are used to control the float and sink of the ROV.

Figure 5 T200 Thruster

In past years, the float and sink of the propulsion system was composed of four 1100GPH bilge pumps. It was rather reluctant to perform well and time consuming for the ROV to move to a desire depth. In order to improve the efficiency of the vehicle system, we decided to replace them with brushless motors which provide a more powerful propelling force to drive the movement of the ROV. By replacing bilge pumps with brushless motors, the mobilization efficiency had been improved greatly. In 2015, we used two Video ray thrusters for controlling the float and sink of the ROV. In 2016, we found that the two Video ray thrusters were too large in height for our design. As a result, we replaced them with two shorter Blue robotics T200 thrusters.

We used only two Video ray thrusters on the two side chambers to control forward, backward, left turn and right turn and two Blue robotics T200 thrusters to control the float and sink of the ROV.

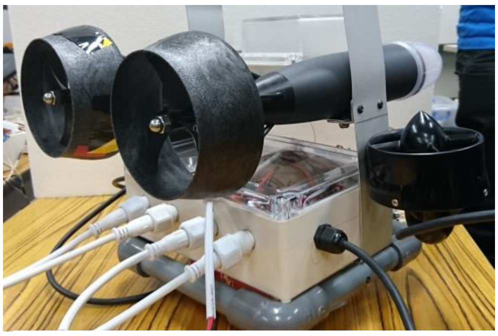


Figure 6 Design of the ROV in 2016

This year, in order to equip both the payload and the rotational arm on the ROV, we needed to further reduce the length of the thruster. As a result, the two video ray thrusters have also been replaced by Blue robotics T200 thrusters which are smaller in size. Moreover, our team would also like to build the ROV so that it can move in all directions (Omni-directional movement) by attaching four thrusters arranged in four corners. Fig 4.9 shows the design of the arrangement of the four thrusters. All four thrusters can generate both forward and backward movement. By applying different combinations of thrusters, different resultant force will be provided to drive the ROV to the desired location.

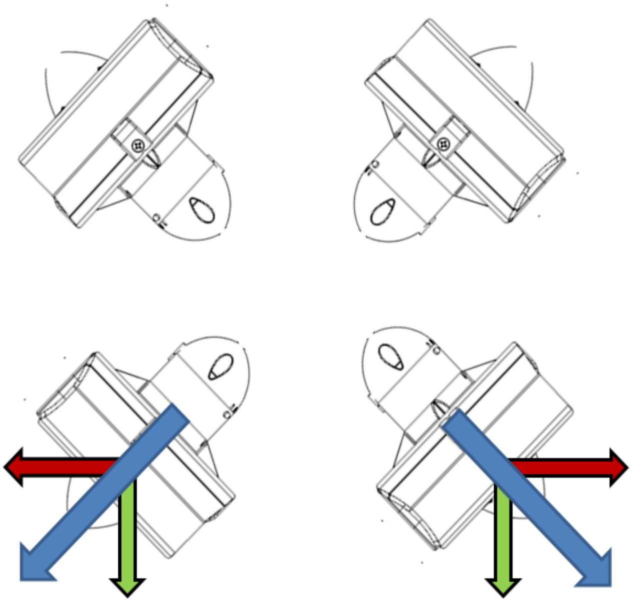


Figure 7 Illustration of forward movement

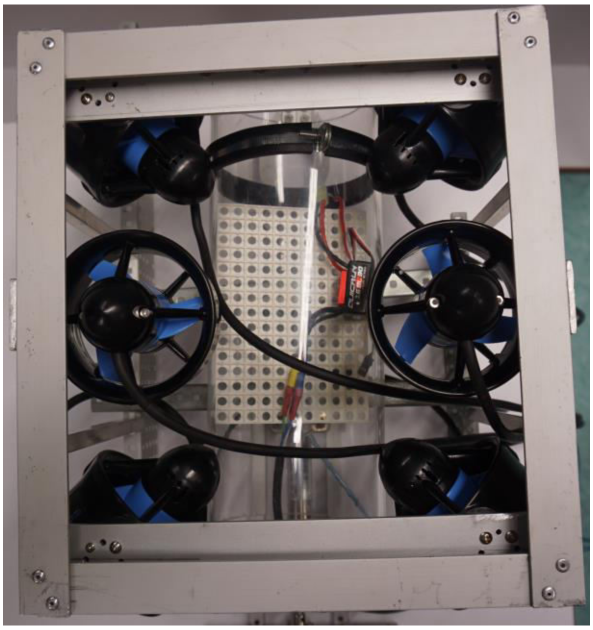


Figure 8 Thrusters positions of ROV

Finally, the performance of the thrusters is better than we expected. High speed movement and all directional movements of our ROV can give us an advantage in moving and searching throughout the competition. Through observations, each single direction of movement is governed by four thrusters together. By comparing our previous design, two thrusters control the movement in two directions only. Now, we have four thrusters controlling all 360 degrees of movement.

In conclusion, by using six blue robotics motors T200 thrusters, we can control the ROV much more efficiently by moving the ROV in all directions, including up and down.

2. Electronic speed control (ESC)

By using brushless motors, an ESC must be used to drive it. An ESC is an electronic circuit used to vary the speed, direction, and possibly used as a dynamic brake for an electric motor. ESCs are used on electrically powered radio controlled models, and often used for brushless motors which require electronically-generated three phase electric power.

We used the ESC to receive the PWN signal from Arduino mega. It varies the switching rate of a network of field effect transistors (FETs). The rapid switching of the transistors can causes the motor to turn clockwise or anti-clockwise and make ROV to move to and fro. There are many kinds of ESCs, some are only capable of moving forward, some are capable of moving both forward and backward with breaking force. Neither of the above two is suitable for controlling the ROV. When the driver wants to control the ROV to move backward, a trigger of backward twice must be sensed by the ESC in order make the thruster start moving backward. The problem is very significant when making a left or right turn of the ROV. As a result, selecting the most appropriate ESC for the brushless motor is very important. A programmable ESC also provides flexibility for controlling the thruster. Fig 4.12 shows the ESC that we choose for our ROV which allow forward and backward movement. At the same time, it is programmable to meet specific needs.

Figure 9 Hobbywing ESC for brushless motors

3. H-bridge

An H-bridge is a circuit that allows a voltage to apply across a load in either direction. These circuits (H-bridges) are used in the field of robotics or other applications which allows DC motors to run back and forth. We use Arduino mega to give out digital signal which controls the H-bridge and used it to control the motor. We use H-bridge to control the DC motor for the rotational arm and provide 12 d.c. for LED light which act as a device for simulation of the RFID scanner.

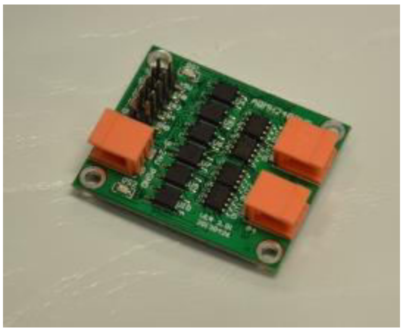


Figure 10 H-bridge

4. Control Algorithm

We used the Arduino board to control our ROV. The ROV is controlled via the program made for the communication between two Arduino boards, which consists of two electronic boards Arduino Leonardo for off shore control and Arduino mega for onshore control of the all motors.

The USB shield is connected to the Arduino Leonardo. The program in the electronic board Arduino Leonardo can convert the analogue signals of the input from the USB shield to digital signals. When the pilot inputs analogue signals via the PS4 game pad into the offshore Arduino control board, the program converts them into digital signals, which is then sent to the offshore Arduino mega board in the ROV through the data transmission wires.

The Arduino mega board inside the body of the ROV then converts the digital signals sent from the Arduino Leonardo board to control the H-bridges, the ESC, and other parts of the ROV, where the Arduino Leonardo board establishes a communication path with Arduino mega inside the ROV. Therefore, different parts of the ROV can be controlled via this communication algorithm.

Arduino Leonardo is a microcontroller board based on the ATmega32u4. It has 20 digital input/output pins, a 16 MHz crystal oscillator, a micro USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller. The Arduino mega microcontroller board can be simply powered by a 7-12V power supply to get started. Because of the simple, open source, low cost properties of Arduino, we adopted it as the communicator and it can process all of the commands instructed by the signal from the Arduino Leonardo microcontroller board, which is controlled by the Arduino compatible USB compatible devices.

The Arduino Leonardo microcontroller provides serial communication, which is available on digital pins 0 and 1. Arduino Leonardo is used to receive both analog and digital signal from the joystick and the buttons respectively. It (Arduino Leonardo) acts as a translator which translates the analogue signal of the Arduino compatible joystick shield into different digital signals, which is then sent to the Arduino mega microcontroller board inside the ROV by using the Serial library of Arduino and the serial communication ports of Arduino boards.

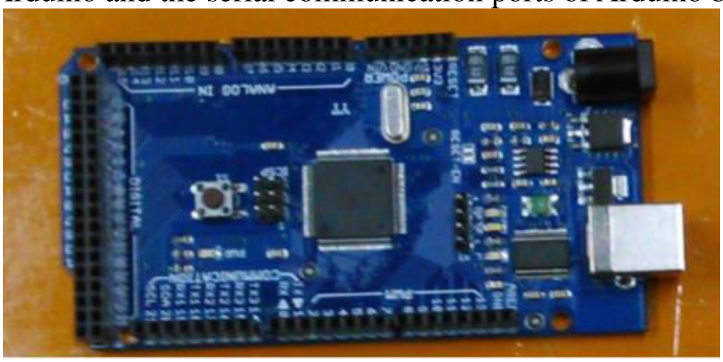


Figure 11 Arduino Mega

Figure 12 Arduino Leonardo

Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins, 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller. It can easily be started by connecting it to a computer with a USB cable, but we decided to use the 12V power supply as the power source of the Arduino mega is located inside the ROV. The Arduino Mega act as a control unit of our ROV. It is used to receive the digital signal sent from Arduino Leonardo.

Figure 13 RS485

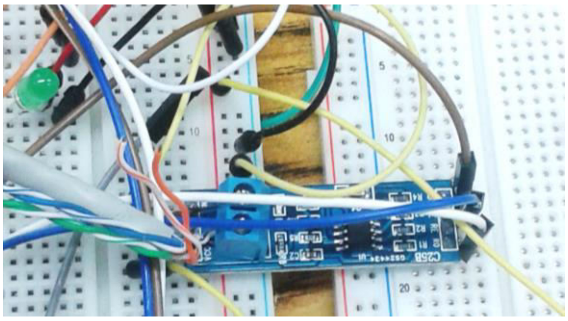


Figure 14 testing RS485 over 30m

A 5-character message packet is made for each communication between control side and underwater ROV. When the ROV is under the water and receives the message packet, it will decode and interpret the data by the program in the Arduino mega and then a series of commands will be executed according to signals received. Afterward, the ROV will behave according to the signals.

5. Gamepad (USB Shield on Arduino)

The Arduino USB shield consists of a USB port to connect the gamepad. This joystick is used to control the propulsion system of the ROV and other component such as the rotatable camera and the pliers. Different actions can be performed by simply pressing two buttons at once or moving the joystick.

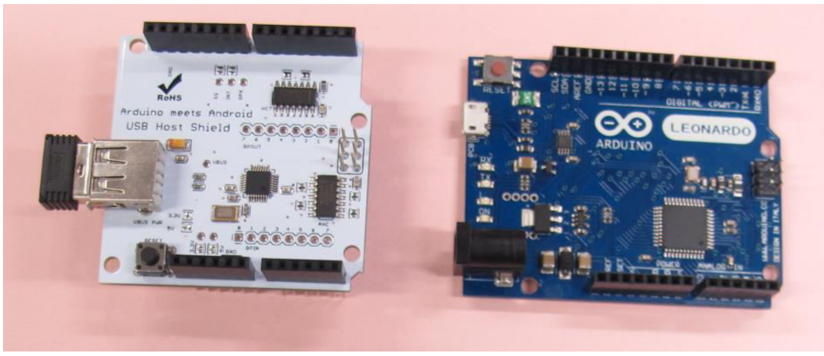


Figure 15 Arduino USB shield, Arduino Leonardo

Figure 16 the PS4 gamepad

C. Pay load - the pliers

Our pliers are designed and constructed for picking up objects and grabbing tools for the ROV. In the past, we have made the pliers with plastic or metal pliers. The opening and closing of the pliers was controlled by either electronic or pneumatic means. Different options have different pros and cons. If an electronic device is used, the speed of opening and closing is slow due to applying a high gear ratio for grabbing the object tightly. In order to make the pliers response quickly, a pneumatic system is adopted for our pay load tool. As a result, the pliers made by metal are more appropriate in terms of strength and durability.

A. Pliers:

The head of the pliers is made of aluminum which is lightweight. The shape is designed to grab tightly objects under water. The pliers is controlled by pneumatics which uses air pressure to push a cylinder to move forward and backward such that it can adjust the pliers to grab and release objects. The pliers can be controlled remotely by pumping and releasing the air in the cylinder through a long wire on land to change its air pressure. The pliers can open widely or close tightly. The object can be picked up and dropped down underwater smoothly by the pliers.

Figure 17 Top view of the plier

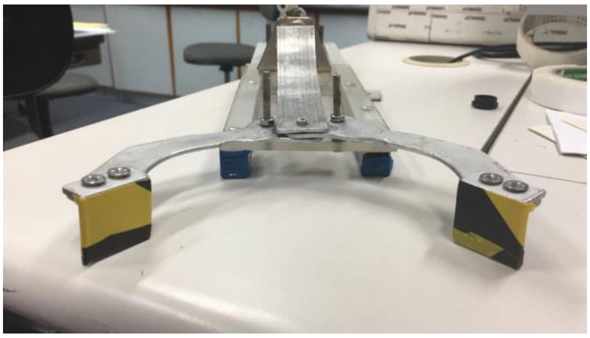


Figure 18 Widely opened plier

B. Pneumatics System:

The pneumatic system works based on the change in air pressure inside different parts of the cylinder. When the pump blows air into the rear part of the cylinder, the air pressure at the rear part increases. As the air pressure becomes stronger than that at the front, the tube inside the cylinder separating the front and the rear part is forced to move forward. The tubing is then extended out of the cylinder and the arm is opened. The principle is the same when making the arm close but the pump has to push air into the front of the cylinder to force the tube to move backward.

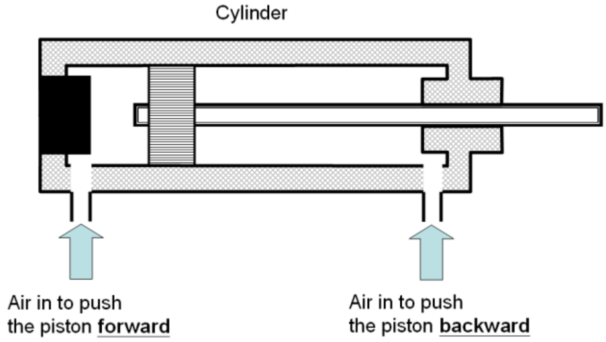


Figure 19 Cross section of a cylinder

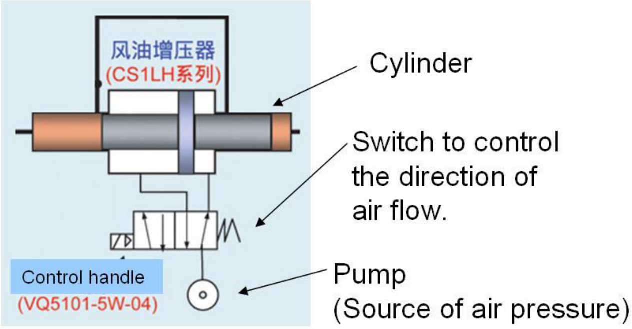
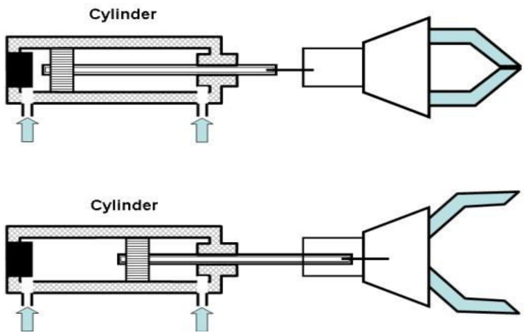


Figure 20 Diagram showing the mechanism of the pneumatic System



Cylinder shrink to close the pliers

Cylinder contract to open the pliers

Figure 21 control Mechanism of the pliers

We control the plier by sending signals from the Arduino board to the leveling valve controller which controls the air flow direction of the cylinder.

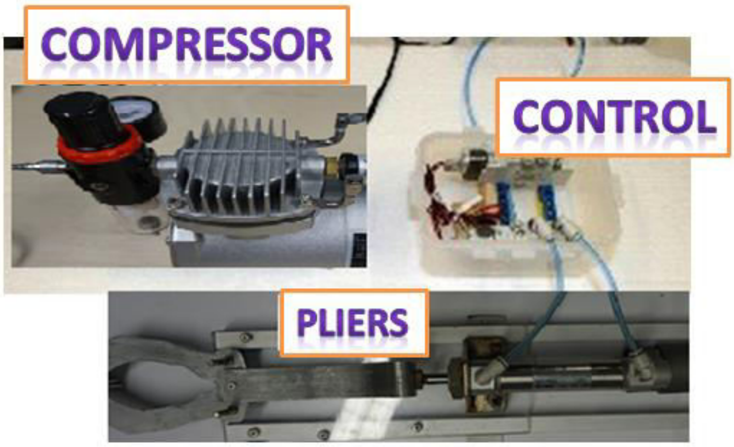


Figure 22 Pneumatic system

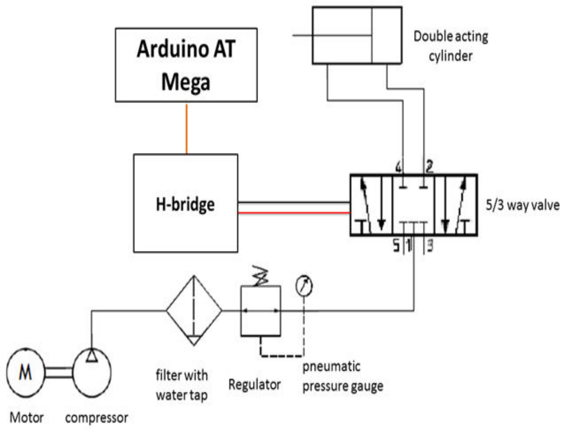


Figure 23 Pneumatic schema

There are a number of tasks needed to be done by pliers, including removing and inserting of the frame, pin, power cable, fountain, etc. We wanted to finish the above tasks efficiently as the time is limited. In the test, pliers controlled by the pneumatic system provided more stable force for the pliers to grab and release objects firmly and quickly.

D. Software

Arduino version 1.61

We used Arduino 1.6.1 to write commands to the Arduino board, which communicates with the board and control the motor by the joystick. Its code is mostly based on the C language, which make us easy to correct and use. It also provides a wide range of standard library, which helps us do our programming job more easily.

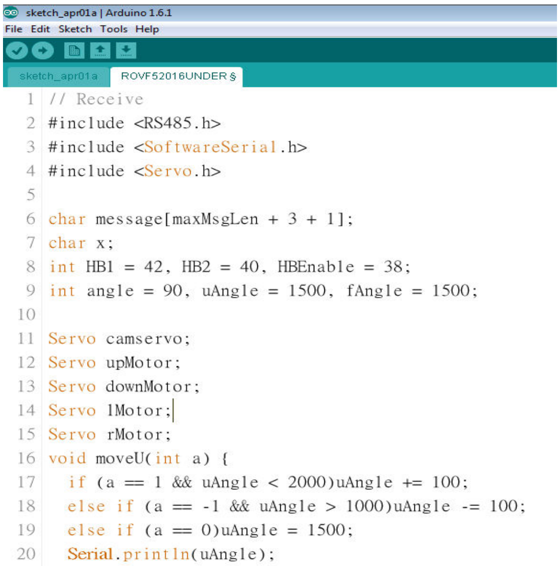


Figure 24 Sample code

The program logic to control the action of the ROV is based on sending and receiving a packet of commands. The control program will send a series of the commands as a packet over time to the ROV. Upon receiving the packet, the ROV will interpret and execute the commands accordingly. The following flowchart helps in describing the logic.

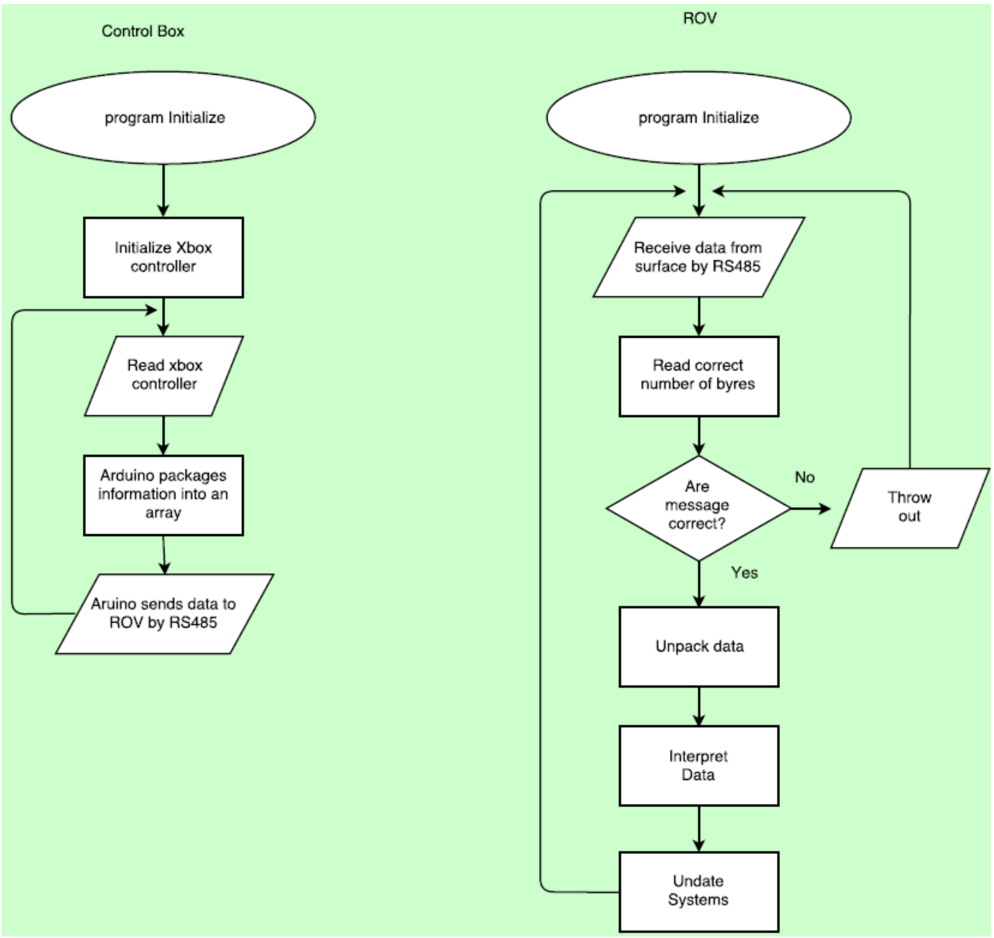


Figure 25 Program Control logic

E.Camera

We put 4 cameras around the ROV for the missions. There are multiple cameras is used and positioned in various parts of the ROV in order to provide different views for the driver to accomplish different tasks.

We decided to fixed camera with size of 2*2cm.Since it is small, it benefit in position the camera. Previous generation of KWOK TAK SENG INC. employed IP camera and web camera, yet the latency of the digital system (IP camera system) increased the operational difficulty. According to Hill et al. , latency can be reduced to less than 60ms in a pure analogue system, and is less than 50% of the latency in a digital system (640X480 with 80% quality).To minimize the latency, analog cameras are applied in the vision system this year.

Figure 26 Camera

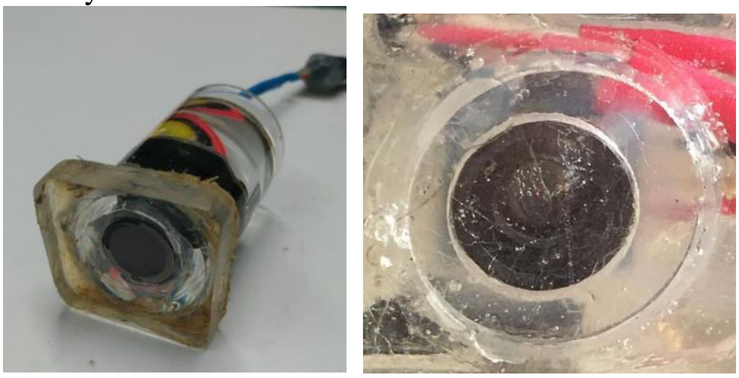


Figure 27 Camera sealed by E-proxy

F. U-shaped Aluminum Rotational Arm

A self-made U-shaped aluminum rotational arm was built in order to turn the valve wheel handle. Since a large force will be needed to turn and close the valve, a powerful motor is needed to give maximum torque. We adopted a much higher gear ratio motor with the attachment of the U-shaped aluminum manipulator to turn and close the value. The rotating speed of the motor is 5 rotations per minute.

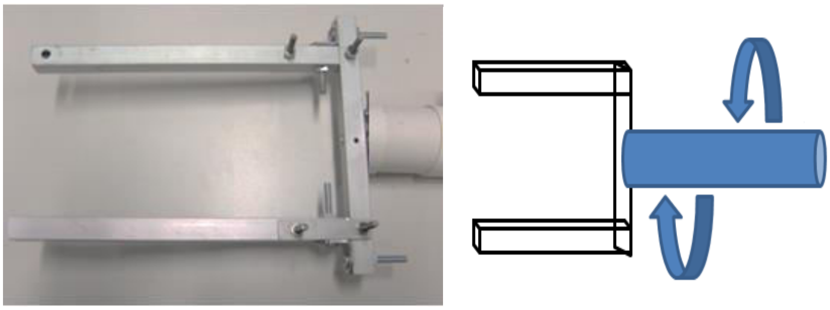


Figure 28 Camera U-shaped aluminum manipulator with high power motor

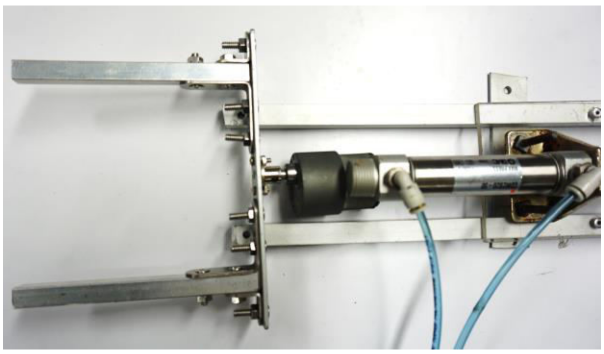


Figure 29 Camera Position of rotational arm located at the rear part of the pay load

G. Sucker

In order to collect the sediment sample from the contaminated area which is simulated by agar, a sucker tool was made for sucking up the agar. The sucker is made by using a metallic cylinder with a hole on the top. The top of the hole is attached with a funnel head. There is a metallic ball trapped inside the funnel head which can freely move under water. The mechanism is that when the sucker penetrates into the agar, the metallic ball will be sucked at the end of the funnel and a negative pressure will be created for holding the metallic ball firmly on the opening and the agar inside the tube will be sucked firmly as well. Hence, the agar will be sucked and stored inside the tube. After collecting the agar on the water surface, we just need to shake the ball to release the negative pressure, and then the agar will come out. It had been tested with the agar we made.

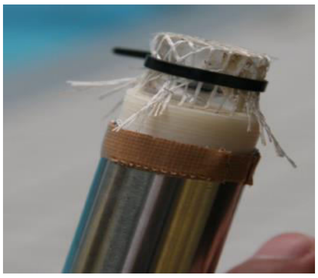


Figure 30 sucker

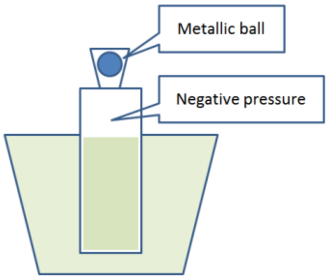


Figure 31 Mechanism of the sucker

H. Waterproof

KWOK TAK SENG INC. electronic system is housed in Poly methyl m Polyethylene ethacrylate (acrylic) tube. Both ends of the tube were sealed by high density polyethene cover. Acrylic was selected instead of polycarbonate because acrylic has the highest transparency to light (92%) in all type of plastic. Also, the price of acrylic is lower than polycarbonate. Acrylic does not contain any harmful chemical bisphenol-A (BPA) like polycarbonate. BPA could affect regulation of sexual hormones to human as well as the growth and reproduction of marine life. As safety and public health awareness is the highest priority for Kwok Tak Seng Inc., material with hazardous chemical is prohibited in the whole design of KWOK TAK SENG INC..

KWOK TAK SENG INC. have tested different brands of epoxy to select the epoxy that acquire strength and toughness for KWOK TAK SENG INC.. Epoxy B was selected, as it provides balance between strength and toughness along with a reasonable price for our large demand.

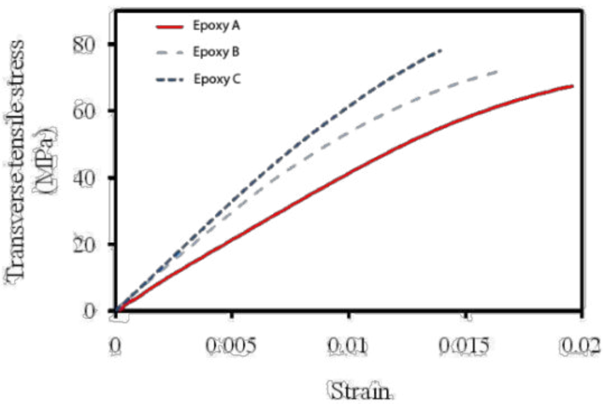


Figure 32 Plot for transverse stress against strain among 3 different epoxy

We use 4-pin waterproof plugs to hold all the wires we need and use tether to twist the wires into one single tube and waterproof the wires.

The waterproof plug is the device utilizing blades which, when inserted into a waterproof connector body, establish the connection between the conductors of the attached flexible cord and conductors connected to the waterproof connector body, having waterproof performance of IP65 (International Protection Code).

They are useful for us since there are many wires we need to use for different aspects as they may twist together and tie each other up. We used a lot of time to fix this problem.

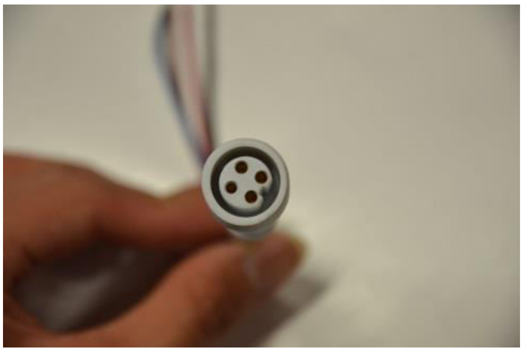


Figure 33 Waterproofed plug (cross section)

Figure 34 Waterproofed plug

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 provide less 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 market and most importantly, we can evaluate the ready-made market product. After the evaluation of both the ready-made product and our skills of craftsmanship, we made our decision.

The following items are too expensive to purchase from market.

Figure 35 ROV body

Figure 36 Pay load (Pliers)

Figure 37 Water proofed camera

Here are tables in capered in the commercial product and self-made tool of the ROV. KWOK TAK SENG INC. found that the commercial product are general expensive than homemade. The design of commercial product requires further modification before adapt to *KTSCSS Dolphin*. Therefore our company decided to self-made Plier and camera for *KTSCSS Dolphin*.

	Pay load (Pliers)	
	Ready-made product	Self-made
Cost($)	$ 2350	$370
Time use(days)	About 10	About 20
Modification difficulties	High	Low
Maintainability	Low	High

	Water proofed camera	
	Ready-made product	Self-made
Cost($)	$287	$80
Time use(days)	About 10	About 5
Modification difficulties	High	Low
Maintainability	Low	High

As for the thrusters and ESC, it is too difficult for high school students to build them. The self-made thruster performance was under our expectation the thrust power is not large enough. Also the developing cost was higher than we brought a commercial product. As a result, we are going to purchase these two items.

After series of research in the commercial product from the market, KWOK TAK SENG INC. found that Blue-motor T200 have a high efficiency of power and most suitable to our use in *KTSCSS dolphin*.

V. Safety

Safety is the most important consideration during construction of the ROV, including protecting the environment and people. When we work, we will follow our safety checklist to minimize the possibility of accidents (cuts or bruises, electrical shocks, defective chemicals) happening in order to protect the members. Besides our members' safety, we consider the environment too. We have tried to build an eco-friendly ROV to protect the surrounding environment, including the undersea creatures or sea structures, as the mission aims at conserving the environment, so our materials are, in part, reused when possible.

We make sure our shoes are tied, toes protected and our clothes tidy, as well as safety glasses being worn. Wires should be placed neatly and not twisted up to prevent stumbling, and tethers added to them if possible. Tools such as scroll saws, drill beds, heat guns, etc., should be switched off while not in use. Soldering irons and glue guns should be unplugged after use as well.

Masks and gloves are always worn when handling hazardous chemicals, like epoxy and chloroform. The process of filling epoxy was done in a good ventilation workplace and 70% Alcohol was used to clean the workplace after chemical pouring.

Thruster are protected by a plastic shelter and labeled with warming tap to raise the awareness dangerous. There are mostly rounded-edges and sharp edges are either protected by plastic tubing or plastic adhesive tapes or being rubbed off or cut. Moreover, various waterproofing techniques are applied to make sure that no water leakage, so that all electronics remain dry. Besides, a fuse is always used to protect the circuit and also the output devices. Plugs are dry to prevent electric shock.

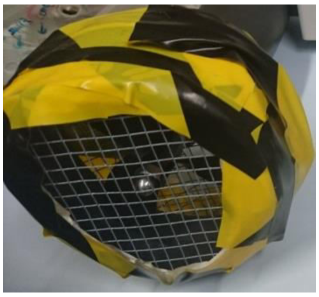


Figure 38 Warming label of thruster

VI. Challenges and Trouble Shooting Techniques

As most of the parts of our ROV are newly designed and made, we encountered plenty of new problems. We all know they need to be overcome.

Programming and the circuit connection were the most complicated parts throughout the ROV project. As the ESC is different from the previous one, each of us tried to code the ESC to transmit signals to the control unit. Although we tried different coding logic, we could not control the thruster’s movements smoothly. When we sent the signal to the thruster, only one side of the thruster moved. We found that the problem was the ESC had a break to protest the thruster. Therefore, we started searching information from web pages, forums and videos to solve the problem. Then we try to use the servo to simulate the signal from the RC controller and send it to the ESC to move the brushless motor. We have successfully completed the program, but the system will have unpredictable suspension. As a result, we searched for a new kind ESC to avoid applies backward twice to simulate a backward movement of a thruster. As a result, we learned a lot of skills in Arduino programming.

In respect to the pliers, we also did a lot of work on making them. As the competition contains many tiny objects, we have designed different forms of the pliers. For inserting the hot stab into the port on the wellhead, a horizontal or vertical plier is not suitable and hard to set at an angle so we designed a rotatable plier. At first, we thought it would be easy to make but we encountered lots of problems, such as the gear ratio, the speed of rotation, etc. We needed to try different types of gears to make it easier to control.

Furthermore, as we put all the electronic stuff in the interior, the space became much narrower than we estimated before. The wires are difficult to place in the narrow interior space. Therefore, we decide to separate the camera from the main chamber of the ROV.

We learned a lesson in waterproofing and had the experience of programming the Arduino. We found that different electronic parts in the ROV need different types of programs. During this year we have learned some advanced programming of Arduino. For example, we have learned how to write a program to control a servo motor. As we didn't have enough programing experience in the past, we needed to do a lot of research to find out how to program the Arduino. We have learned how to sort the data and basic data analyzing skills. We also used a CPP program to send the signal to the Arduino board. We also learned how to use the most suitable type of Arduino board. Owing to the various types of signal wires, chipsets and shield, especially the 25 - pin signal cable, soldering the wires is not an easy task. Lack of spare time of the servo motor also slowed our progress. Our programmer had to do more work at school in order to reduce the time spent on the project.

We need to plan different posts for different people. From this experience, we have learnt more about the intensity of division of labor and also how to communicate and help each other within our team. Lack of communication will not help us finish our work.

We also learned how to plan to put the board in our ROV. It was difficult to plan the design of our ROV as the board has many wires, characteristics and uses.

VII. Further improvement

In creating a new ROV by original and authentic materials to accomplish every task stated in missions, we have done a lot research and interviews from past students to acquire more knowledge about building an ROV. We adopted their advice to use high efficient thrusters with the appropriate ESC. For further improvement, we plan to modularize each component with water-proofed electronic plugs. Which benefit in maintained and replacing of failure parts.

The circuit board had already been redesigned to suit different electronic devices. It is suggested that more general boards can be built to suit any other components. The circuit board design should be designed by computer software and printed by a professional circuit board company instead of using cables to build the circuit.

In addition, the frame could be streamlined. The streamlined shape has smooth and regular surface without corners, and can reduce the turbulence during moving, hence reduce the water resistance and increase the speed.

VIII. Reflection

When we think about the time we spent on the ROV project, it is an unforgettable experience and we really learned valuable lessons during the preparation time.

The preparation time contained joy, sadness, hopefulness, anger, and regret. Although we spent a lot of time of creating the ROV and paid almost no attention to our schoolwork, it is worth the while for us to put so much effort into this project.

All of us are willing to sacrifice for the ROV. All of us have had experience in this type of project before so we can reduce the errors and construct the ROV easier. However, as the tasks are a bit different and the improvement of our ROV important, other problems arose so we were able to learn more and more new skills together.

Most of our time doing the ROV was happy and joyful. We enjoyed the time in our workplace which is a normal computer room. We always stay there and it becomes our second home. We played, ate and built the ROV there. Somehow, we got into arguments about the design and the programs. Luckily, we can try out our own opinions and figure out the problems together.

We felt free when constructing the ROV because our teacher gave us the chance to try. However, we often got punished by our teacher when we did something wrong. Fortuitously, those errors helped us find and solve the problems easier. However, some of us may have felt sad about it. Therefore, we will encourage each other and build friendships. This will improve our problem-solving skills and help us understand our own shortcomings.

To some of our members, this will be the last competition they will participate in. We will try our best to finish the ROV and put a wonderful end to our school life. More than that, we cannot keep working in school all day and some members are from Form 5. They need to have extra lessons. That was a great challenge for us as we thought we might not have enough time to do it. But all of us realized that and didn't give up. Finally, we finished the project in a limited time. At last, we finished our work in about three months. We all felt proud, but still cannot relax, as the competition is coming and we all feel hopeful.

IX. Company Social Responsibility

Kwok Tak Seng Inc. helped coordinate ROV workshops to help local and international participants foster and develop skill sets and knowledge to build their ROV’s. Also, **Kwok Tak Seng** Inc. has given sharing to the Tai Kok Tsui Catholic Primary School and Ma on Shan Ling Liang Primary School. We hope to inspire the young to get involve in this filed. Also we have join the Maker Faire 2017 to give an opportunity for the participants to control the ROV to perform basic operations underwater.

 Figure 39 Cooperation of teams in making ROV	 Figure 40 Making of ROV

X. Project Management:

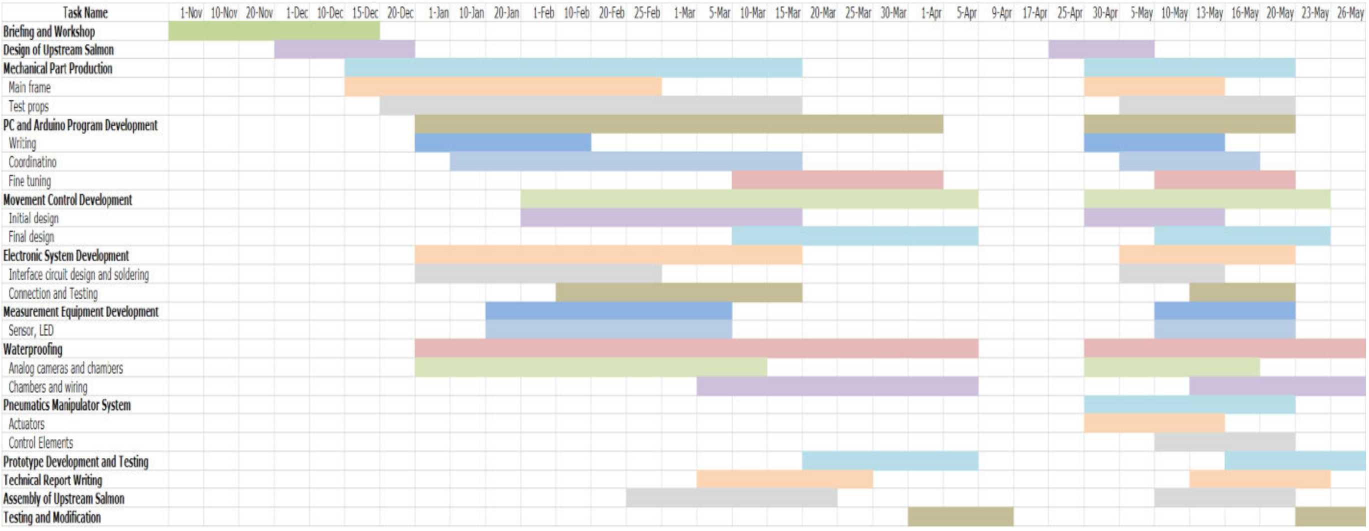


Figure 41 Gantt Chart

To complete the development of KWOK TAK SENG INC. on time, a Gantt chart is used for scheduling generic resources as well as for project management. The CEO of KWOK TAK SENG INC. delegates responsibility for the heads of each departmental unit at each workday, who in turn lead their corresponding employees in building tasks and deliverables required by MATE before reviewing and updating the chart. Deadlines are encouraged to meet where on unreached goals, employees worked between workdays and those who done their tasks on time nicely and skillfully could be motivated to take parts in other interesting duty to help them develop their interest and practical skills.

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XII. Acknowledgement

KWOK TAK SENG INC. would like to express their deepest gratitude to the following sponsors: Kwok Tak Seng Catholic Secondary School for the funding and support, Department of Electrical Engineering, PolyU– for providing mentor tour; MATE Center – for organizing the international competition, providing a platform for the growth of the entire community, and being the origins of the competition; The Institution of Engineering and Technology, Hong Kong – for organizing the Hong Kong/Asia Regional of the MATE International ROV Competition.

Appendix I - Budget

Category	Estimation (US$)
Administration	125
High power Thruster	975
ROV main body	170
Camera	37.5
Electronics	125
Cable	80
Others	200
	1712.5

Appendix II - Safety Checklist

Safety Checklist Form

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

Safety checklist items	☑	Remarks
Pilots and ROV tether controllers at all times:		
1. All people wear accurately tied or closed toed shoes.		
2. All people wear safety glasses		
Before the ROV deport to the water: (Mechanical inspection)		
1. All components are attached firmly		
2. All dangerous parts are identified and protected		
3. All dangerous parts are identified and labeled as dangerous		
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 thrusters 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. Check the connection of main power supply		
3. All plugs are dry and securely attached		
4. Unused plugs should also be shielded		
5. All connections are labelled		
6. No wires are exposed / No open ended wires.		
7. Ensure the input voltage matches the expected		
Overall System Checklist		
1. Ensure all thrusters function properly (UP,LEFT,RIGHT)		
2. Payload functions properly (Open, Close)		
3. Payload Rotation (Rotating clockwise and counterclockwise)		
4. Rotational arm (Rotating clockwise and counterclockwise)		
5. Cradle head movement of Camera (Rotating clockwise and counterclockwise)		

Sign of the first Staff: ____________________

Name of the staff: ____________________

Date and Time: ____________________

Sign of the Second Staff: ____________________

Name of the staff: ____________________

Date and Time: ____________________