Company: Narwhal

School: Keang Peng School (Secondary Section), Macao

Team members:

Lou, Weng Keong (Madao): Prime Mechanical Engineer & CEO

Cheong, Chi Kit (Kid): Electronic Engineer & CTO

Io, Hong Wai (Wai Gor): Vice mechanical Engineer

Mok, Kuai Un (Alex): Graphic designer & Instruments director

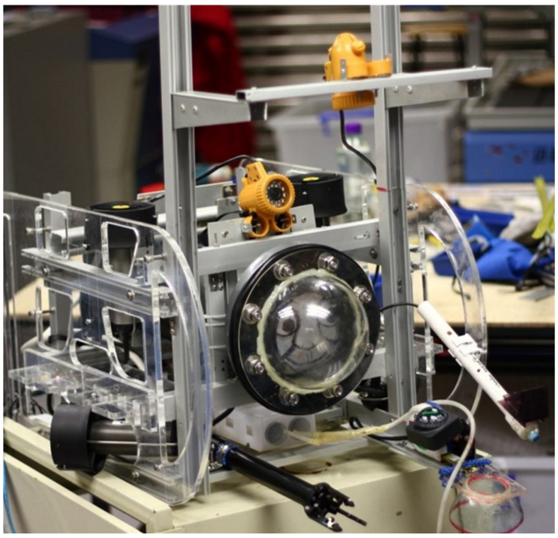
Lou, Cheng Nong (Phillip): Graphic designer & Chief pilot

Kan, Hok Tim (Frankie): Mechanical trainee & CFO

Instructor:

Thomas Lao, Programming design teacher in Keang Peng School

Bevis Leong, Computer Science student in University of Macao

Narwhal	
	ROV

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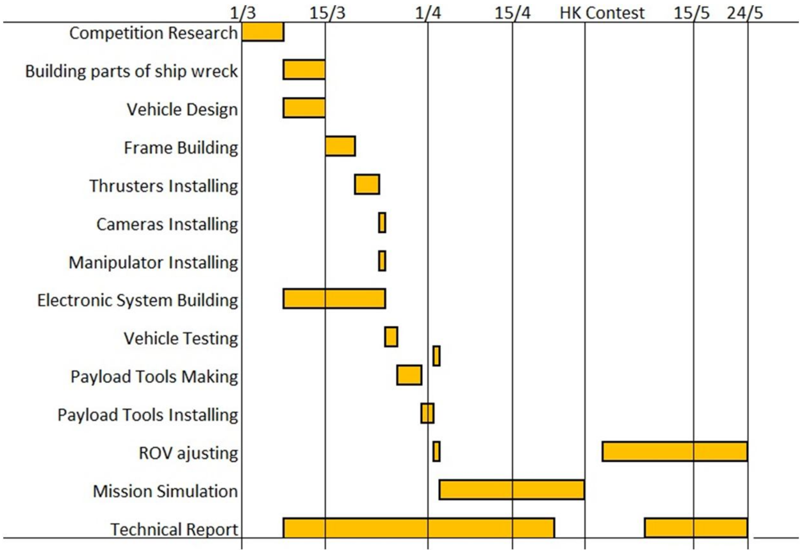
Abstract

Narwhal is a pioneering ROV company founded by 6 ambitious teens, whose concept is "Establish the first underwater dynasty in the World". Various types of ROVs have been designed by Narwhal for deep sea rescue, underwater recourse exploitation and educational use.

Thousands of shipwrecks have been sleeping under the sea for over 70 years from WWII until now. The risk of oil leakage of those wrecks is still a severe threat to the ecosystem. In terms of feasibility and efficiency, ROVs play important roles for retrievement of fuel oil and precious relics from wrecks. So this time we designed a ROV called Narwhal to explore the wreck site and retrieve the oil and other materials. Furthermore, ecologic environment can be saved and more underwater mystery can be unveiled with the assistance of Narwhal.

Schedule



Because 4 freshmen join our Narwhal Company, we decide to use less than half of the time to build the ROV and let them practice to control our ROV in the rest of time. During the process of building Narwhal ROV, we let them do as much as they can. Now, they have already had the ability of building a new ROV!

Design rationale

Frame

Narwhal ROV is mainly constructed with aluminum and 9mm acrylic sheets for rigidity, anti-corrosiveness and popularization. The frame can be divided into two parts --the props and the exteriors (Figure 1 & Figure 2). Props are built with aluminum strips because metal is able to support the weight of ROV. The exteriors of Narwhal are constructed with acrylic sheets because of the ease of process. There is also a platform installed at the bottom of Narwhal, which allows us to mount different kinds of pay load tools.

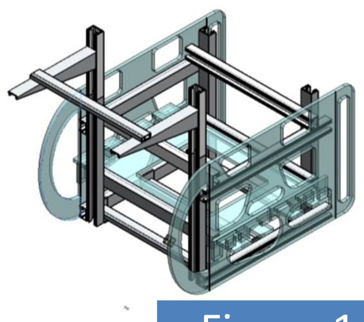


Figure 1

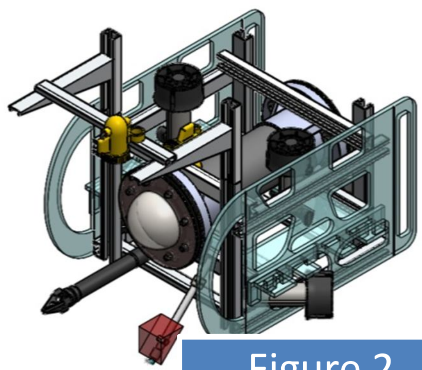


Figure 2

Propulsion system

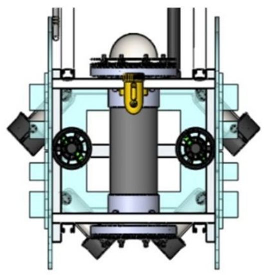


Figure 3

Six Seabotix thrusters (Figure 3) are mounted on the acrylic frame of the ROV to provide the propulsion for Narwhal. Each positively-buoyant thruster works under 12 volts and maximally provides 28.4 N of thrust. Thruster dusts are mounted for each thruster in order to improve the stability of propulsion system and protect propellers from damage.

Considering Seabotix thrusters are powerful enough, two Seabotix thrusters are used for vertical movement. And we respectively assembled four thrusters at four corners of ROV to provide the horizontal motions. Although using four thrusters instead of two increases the weight of payload, the pilot can maneuver the ROV with accurate horizontal orientation by using a joystick-based control system.

Electronics housing

Last year, we put all onboard control unit in a waterproofed case installed on the top of the ROV. With the experience of MATE 2011, we realized the advantages of using column-shape electronic housings which is pressure proof. So this year we try to use a flange to make the electronics housing. And to make our ROV easier to repair, plugs are deliberately installed at the rear of the flange for the connection between inner electronic unit and external tether (Figure 4 & Figure 5). As a precaution, we paint the water-resistance paint that we used last year on the circuits to prevent short circuit.

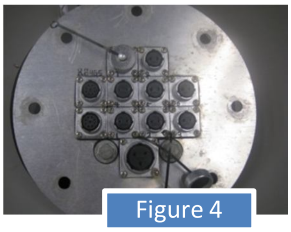


Figure 4

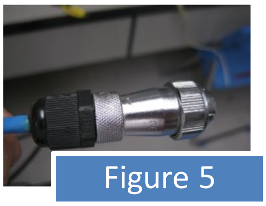


Figure 5

Electronic

Communication with RS485

The control system we used is divided into two parts, a control panel and an on board control unit. 2 microcontrollers (Arduino) is used for both control panel and on board control unit. And we used the built-in Serial protocol for communication. We deeply realize that if we want to transmit data from sheer to ROV in long distance stably, a robust long-distance communication technology is required to form a feed-back control system, thus, we use the IC RS485 which allows relatively long distance signal transmission up to 4000 feet (Figure 6). We use a pair of Arduino and MAX485 to communicate between sheer and ROV with long tether.

Not only stable long-distance communication is guaranteed, but also thinner and fewer cables are used in this case, thus, the cost and the weight of our ROV are significantly reduced. In addition, if you want to have some changes of the program or debug, you just need to download an amended program to the Microcontroller without any hardware modifications.

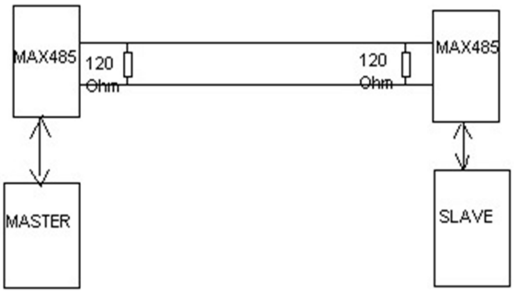
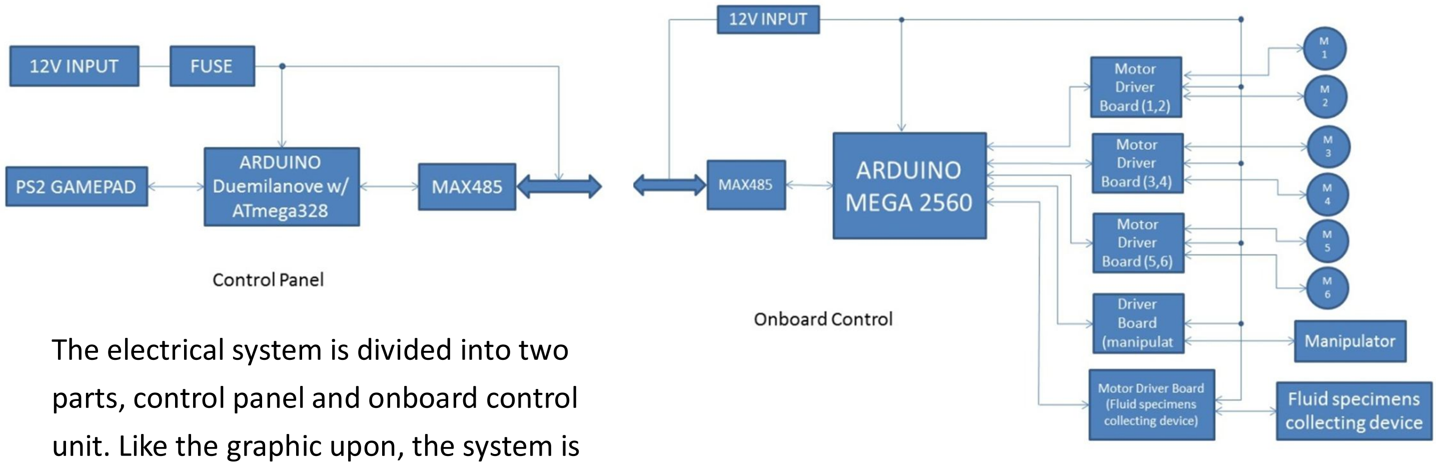


Figure 6: Base connection using RS485

Electrical Schematic



The electrical system is divided into two parts, control panel and onboard control unit. Like the graphic upon, the system is worked under 12V. There is a fuse between the power source and the control panel. The Arduino of the control panel will read the data sent by the PS2 gamepad, then it will transmit the data to the onboard through MAX485. After the Arduino Mega of the onboard control unit receives the signal, it will transmit the corresponding PWM signal to the Motor Driver Board to control the motors or different devices.

Control panel

Figure 7: Control panel for sheer

Learning from last two years' experiences, we let go of just using dozens of switches with which it's really complicated for us to steer ROV, instead, we tried using gamepad as the main control interface (Figure 7). The PS2 gamepad communicates to a transiting device which is fused (Figure 8) to transmit signal to the onboard unit. Using a PS2 gamepad is a great innovation, it allows pilots to manipulate the ROV more directly and handily, the horizontal movement (parallel move and turning) can be under control only by using one hand. Accompany with the ability of velocity modulation, the stability of working underwater has been highly increased. Pilots can just pick up a pocket controller like the PS2 gamepad that we used to finish all the operations. Once the moving becomes easier, pilots can pay more attention on the main task hence the successful rate of accomplishing the tasks will absolutely be higher.

Figure 8: fuse

Onboard unit

We preferred to build our ROV with an onboard waterproofed console containing the core circuit (Figure 9) of ROV. With this meticulous design, we can deploy our ROV with merely two pairs of wires; one is for power source while the other is for control signal and data feedback. Furthermore, the waterproofed console also provides floatation for ROV. Isn't it a method of killing two birds with one stone?

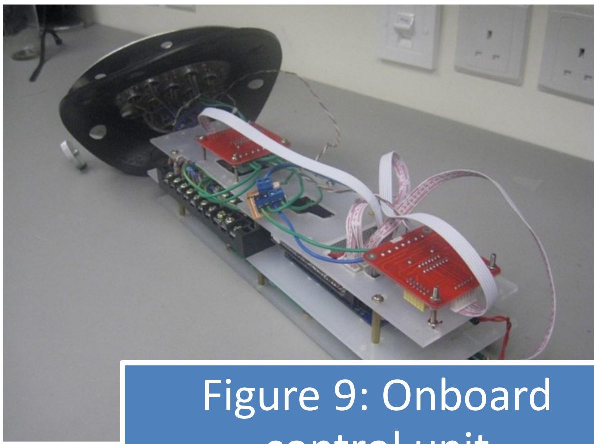
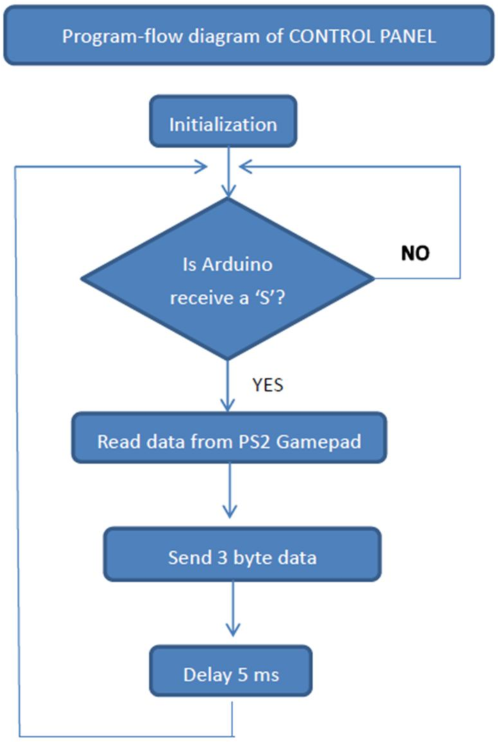
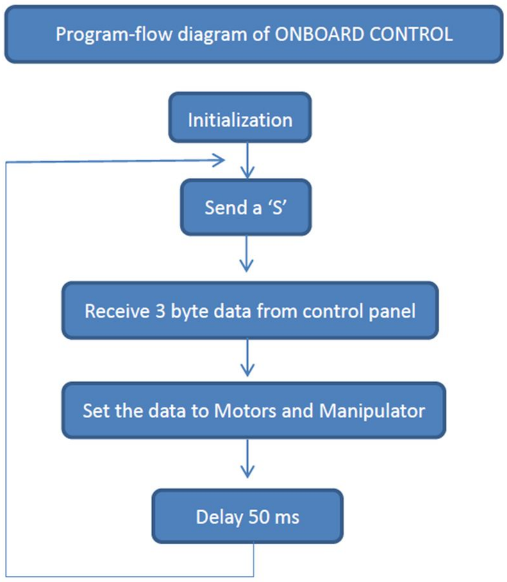


Figure 9: Onboard control unit





Tether

Experience show us that is a pile of tethers are attached to ROV, the tethers will became an obstacle of the movement of the ROV. That's why we want the tethers in use as few as possible. Having set up an on-board circuit unit on our ROV, we are able to merely 4 tethers connected between the ROV and the control panel (Figure 10). Two of them are for video signal captured by cameras, one is for power supply and the one left is for control signal transmission. Finally, we have tied them up in case the cables get knotted.

Figure 10: Tether

Camera

It is not easy to completely waterproof a camera, so we decided to use waterproofed cameras directly. Where to place the cameras directly relates to whether we are able to accomplish the task. We put two cameras (Figure 11) on our ROV. One is put on the top of our ROV to focus on the manipulator and other payload tools. Another is put at the front of the ROV to have the forward sight. As a result, the pilot can use the two "eyes" to finish all the tasks.

Figure 11: Cameras

Manipulator

This year we use a Seabotix manipulator (Figure 12). It draws a maximum of 4 amps of current and works under 12 volts. The manipulator is three-pronged and the arm has maximally 100 kg of gripping force. So it can hold objects more stably than the one we used last two years. We install the manipulator on the right side of our ROV because we can have more room to put the other payload tools. Manipulator is mainly used to finish missions such as coral gripping the coral and the lift bag.

Figure 12: Manipulator

Payload tools

Metal sensor & simulated sensors

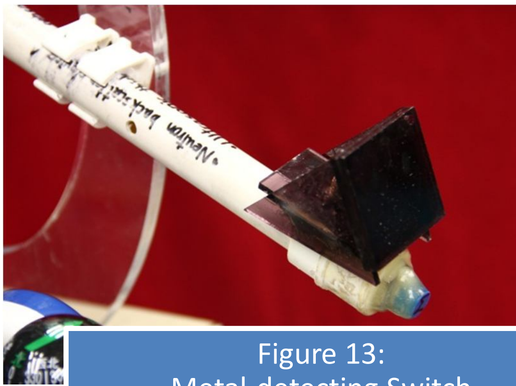


Figure 13:
Metal-detecting Switch
& Simulated Sensors

We install a metal-detecting switch (the blue one of Figure 13) which switches on only when it touches metal. The switch is used to detect if the debris piles is metal because of the short valid detecting scope of it. We put the switch in a 1/2-inch pipe and glue it with the pipe to do the waterproofing. After it is connected to the on board unit, we can determine if things are metal through the state of the indicator light on the control panel. In another word, the indicator light shines once metal is detected. Because the debris piles are all at the bottom of the pool, to make the pilot work more easily, the metal sensor is installed with a 30 degree beneath horizon. And we also combine the ultrasonic thickness gauge and the neutron backscatter device into one unit. We use 3mm acrylics sheets to make the unit (the brown one of Figure 13).It is installed on the pipe where the metal-detecting switch is installed. There is a surface on the unit so our ROV can touch the ship wreck with the surface stably.

Measuring tape

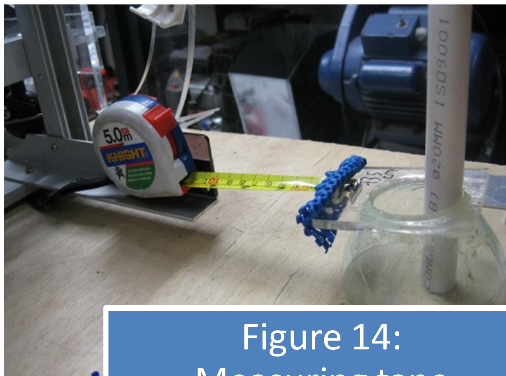


Figure 14:
Measuring tape

ROVs are required to measure the length of the shipwreck in task 1. The device we used to accomplish the measurement is a measuring tape (Figure 14), which is installed at the front of Narwhal ROV. We also make an acrylic sheet with a hole at the front of the tape. To attach the pipes painted red and yellow on the wreck more easily, there is a hood installed under the acrylic sheet. With the “hood-like hook”, the pilot can attach the pipe more easily.

Compass

To determine the orientation of the ship, a compass is required. But there is a problem remaining—the pointer of round-type compass will be stuck if it is not keeping horizontal. Instead of using a typical round-type compass, we prefer to use a Spherical (Figure 15) compass. Because the pointer of it can turns to horizontal automatically, so we don't need to worry the pointer get stuck.

Figure 15: Compass

Fluid specimens collecting device

Fluid specimens collecting device consists of motors, syringes and plastic tubes (Figure 16). We fixed the plastic tube at the front of the syringes, and then linked up the motors and the syringes by wires. The physics principle behind is that difference of pressure makes liquid sample be absorbed. There are advantages which pump can't replace is that it declines the payload and the electricity required from ROV. We can have different amounts of sample by using syringe with different capacities.

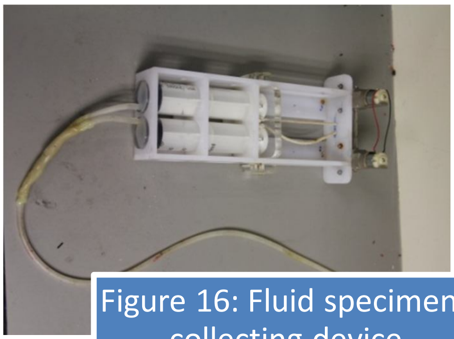


Figure 16: Fluid specimens collecting device

Safety features

There are caution marks on the hood of the thrusters (Figure 17) to remind people to keep high safety awareness constantly while working with thrusters and propellers. An emergency switch and a fuse are also installed on the control panel (Figure 18). Once the system malfunctions, we can switch off the system with the emergency switch manually.

Figure 17: caution mark

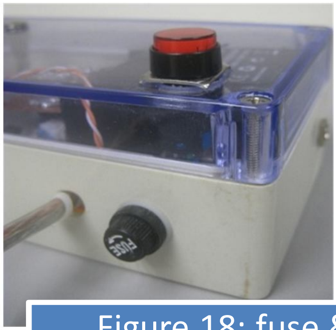


Figure 18: fuse & emergency switch

Challenge

Trying new materials

The frame of the ROV we designed last year is vulnerable because the material we chose, PVC pipe, is not strong enough to support the weight of ROV. So we try to use aluminum materials and acrylic sheets to build our ROV this year. It is the first time for us to use those materials, and we take a great deal of time to test the strength of those materials, as well as trying to combine aluminum strips together. After many times of failure, we finally found the pop rivet which can join the aluminum strips together. And we also install angle irons to strengthen our frame.

Go with 4 trainees

Since one of our members has gone to university while the other one has to focus on his own study, there were only 2 members left in Narwhal ROV team this year. Fortunately, 2 new enthusiastic members came to join us. As they were all newcomers of ROV, so we, the 2 high school guys, have to take time to teach them how to use the tools and how to design a ROV. And we let them try making the ROV just like we the first time we do. We also tell them how to summarize the experiences and do better. And now, they have already had the ability of building a new ROV!

Troubleshooting

Waterproofing

In any circumstances, waterproofing is the most important technique of building a ROV. And this time we try to use a flange to make the electronics housing. There are 8 screws around the flange, and we use 2 aluminum board and the rubber ring as the cap of the flange. The method we use is put the rubber ring between the aluminum board and the flange, then tie the screws. But we found that if we tie the screw too tightly, the aluminum boards will deform. To prevent the aluminum board form deformation, we try to count how many rounds should we turn the nut to prevent the housing from leaking, as well as deformation. When we tie the screws, the screws will press the aluminum board, the rubber ring is also pressed. So we can waterproof the flange. And we count how many rounds we tie, so we can control the force giving by the screw to avoid the deformation of the aluminum board.

Lack of space for electronics housing

In our electronics housing, there is lack of space for us to put all the circuits in. To solve this problem, we design a structure like a sandwich and put the circuits on the different layers. Then we stock the circuits on different layers. So we can gain more space where we can put piles of circuits in. There are three layers of the sandwich-like structure. And the circuits from different layers are connected, so we can use the same among of circuits with a much small space. With this technique, we can add more function to our ROV without the trouble of no space for more circuits.

ROV testing


we are ajusting the buoyancy of Narwhal

We also tested our ROV with the small pool of our school. The depth of water is just 70cm. Although we cannot make the whole wreck of the mission because of the depth of the pool, we try to use the PVC pipes to make the parts of the wreck. We have test the device installed such as manipulator, measuring tape. After testing the device, we can know how many time we spend in each task, then we write a schedule about what should we do during the 15 minutes mission time. For a further test, we also go to the Sai Van Lake to test the movement of Narwhal ROV in deeper water.

Lessons learned

We have learned many meaningful lessons during this activity. We all agreed that the most important skill gained is the ability of working smoothly with the teammates. During the process of making a ROV, we have ever quarreled just because of the a little decision. But after we cooperate for longer time, we start to learn how to help each other to get out of dilemma. We work just like a big family.

To build our ROV, we go to find the suitable component whose name we don't know. Then we go to the shops and ask. If the shop we ask doesn't have the product, we need to ask for more information such as where to buy. Finding suitable parts is also an adventure to us, which makes us become braver and learn how to communicate with others.

This year, we try to use many new technologies to build our ROV, just like we use the flange to waterproof our circuit boards. During work on waterproofing of the flange, we know more about the materials and structures of different o-rings. We found that using the softer one is easier to waterproof. And we found that even the plugs we use in electronic housing are not safe enough to avoid leaking. So we glue the bottom of the plugs to prevent leaking.

Also, we learned how to develop an onboard control unit better for our ROV. The one we make this year is more systemized. With that, Narwhal ROV's tether becomes much thinner than last year's one. We found that thinner tether not only give us the ease of transporting Narwhal, but also makes it move more smoothly underwater.

Reflections

Madao

Building a ROV is a difficult work for only a person, but it's not a hard work for a team. In these months, we have ever got into trouble, and we thought out the solution together. When we finished one part, we all were very excited. In this process, we share happiness, we also have much fun. In this period of time, we build our ROV from 0% to 99%. You may ask why I say that our ROV is just 99% finished but not 100%, it's because the evolution of our ROV never ends. In this process, I not only gain experiences of building ROV, but also gain reliable teammates.

Kid

It's the second time for me to get involved in MATE international ROV competition. I feel really glad that I have an opportunity to work with my group mates. In spite of being misled by red herrings at the very beginning, we all worked at a same goal in a nice atmosphere. I always relive the day when we are working at school until 10pm because I believe that "No pain, no gain".

Also, I become more skillful to program Microcontroller, Last year our ROV can't do more than one action in the same time, but this time I improve the program that it can be controlled by pilot naturally.

Wai Gor

I have learned a lot that I may not able to learn from formal lesson while working with ROV. I am in charge of waterproofing part and the frame design. Although waterproofing the flange is quite a hard work, we have finally made it. It is because the way to make the Flange waterproof is always changed before we find the best way, so we have failed sometimes. But I have never thought of letting go of it. I learn how to insist on doing a mission, even a "impossible mission".

Alex

Joining the Team, I have tried many new and interesting things and some useful technique, such as soldering and Arduino programming. At work, I know more about my teammates and my seniors. I learn how to communicate and cooperate with others. I also become more confident.

Phillip

I think that I have benefited a lot. For example, I improved my physics, maths knowledge. I learn many things such as programming and soldering. In the process of designing Narwhal ROV, I learn that teamwork and self-independence are both important. Even though I've failed many times, but I strongly believe that if I don't give up, I can overcome all difficulties eventually. The saying that “as long as there is perseverance, the pillar on the ground into a needle.” impressed me the most. When I work with a team of even work alone, the experiences will surely become powerful “weapons” to the works!

Frankie

I have improved my practical ability and I have learnt how to use different tools to finish the task. In this several months, I learn how to use the laser cutting machine and see some interesting machines that we have never seen before. During the process, I become more interest in science, and want to know more about the technique used in the ROV of others. I also became more patient and learn more extra-curricular knowledge.

Future improvement

Actually we have bought a powerful IP camera which provides 360 agree panoramic view. With the IP camera, we can only use a camera to see all the forward sight. It means we don’t have to install a camera specifically to look at the how the device operated of our ROV. And we can also have different angles of eye sight to know more about the environment surround the ROV.

In fact, we are trying to make a good waterproof case for the IP camera. If it comes to reality, all cameras of ROV can share a network cable. Then we only need to use two tethers between the ROV and the control panel, which can also help our ROV to move underwater more smoothly.

Budget sheet

Incomes:

1. Financial support from Keang Peng School for building materials: HK$ 2,913
2. Financial support from the Science and Technology Development Fund of Macao for building materials: HK$ 40,000
3. The money left is paid by the fund of Narwhal ROV team

Expenditure table for materials

Item	Quantity(per piece or per batch)	Price(HK$)	Total(HK$)
PVC pipe	1	50	50
Flange	2	180	360
PVC pipe for Flange	1	10	10
Bolts and nuts	16	8	128
Aluminum materials	1	255	255
Acrylic Board	3	100	300
Measuring tape	1	15	15
Compass	1	15	15
Aviation plugs	11	30	330
Camera	2	125	250
Power cable	15(m)	1500	1,500
CAD 5 network cable	15(m)	Sponsored by School	-
Manipulator	1	19366	19,366
Seabotix Thruster	6	5821	34,926
H-bridge motor driver circuit board	3	70	210
Gearbox	2	30	60
Syringe	2	5	10
Arduino Mega 2560	1	135	135
Arduino Duemilanove	1	75	75
Wireless PS2 Gamepad	1	50	50
Elemental electronic component	1	100	100
Total	HK$ 58,145		

Acknowledgements

Marine Advanced Technology Education (MATE) Center – thanks for holding the competition and gathering the ROV builders from different places.

The Science and Technology Development Fund of Macao – thanks for donating us the money of building material

Keang Peng School (Secondary Section) – thanks for donating us the money of building material, supplying us the venue of testing our ROV and the supply of the tools

Thomas Lao and his lovely family – thanks for giving us opinions, the support from the spirit and giving up his time afterschool

Our families – thanks for the support from the spirit