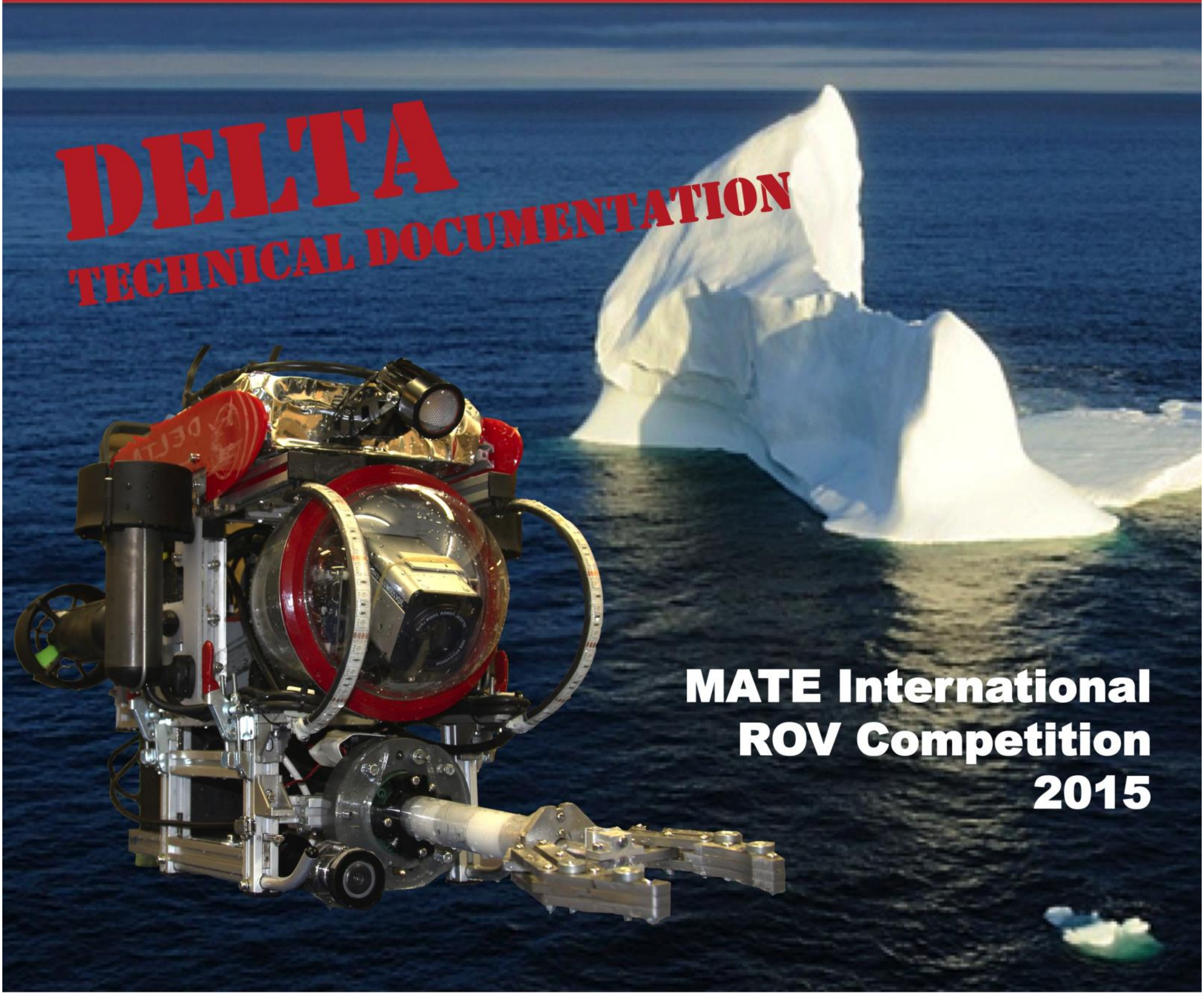
CMA UNDERWATER EXPERT LTD.



DELTA
TECHNICAL DOCUMENTATION

MATE International ROV Competition 2015

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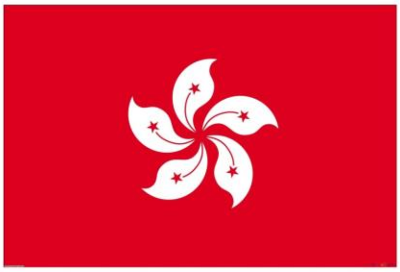

HONG KONG

CMA SECONDARY SCHOOL, CMASS ROBOTICS TEAM

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Abstract

The rich subsea asset has long been valuable to humankind and beneficial to marine research and observation. To work under an extreme environment like the Artic in St. John with endangered bowhead whales, icebergs and stationed oil platforms around, a perfectly performed Remotely Operated Vehicles (ROV) is required.

The ROVs built by CMA Underwater Expert Ltd. has the capability and technology to support the polar science community and the offshore oil and gas industry. Authenticity has always been our company's remarkable strength. We have been working on perfecting the design and function of ROVs since 2008. ***Delta***, at the smallest size of 450mm x 380mm x 400mm among Explorer Class, is custom built and mostly made of authentic materials. Together with its highly integrated onboard all-in-one control panel, it is capable to collect samples, repair pipelines and maintain oil platforms conveniently, safety and flexibly.

We aim to make ***Delta*** a tiny, robust and functional ROV. ***Delta*** is well equipped with handy manipulator and powerful thrusters with its unique illuminating system including a DOME camera with seven side cameras to work in the dark. Under the advanced quickly detachable mechanism, ***Delta*** could be divided into three parts whereas all mission-specific auxiliary tools such as algae collector, valve controller, voltage detector and liftline could be easily installed and removed. It is designed for both safety and logistic concerns.

This technical report details the development process and design rationales that make ***Delta*** the best ROV for the MATE contract.

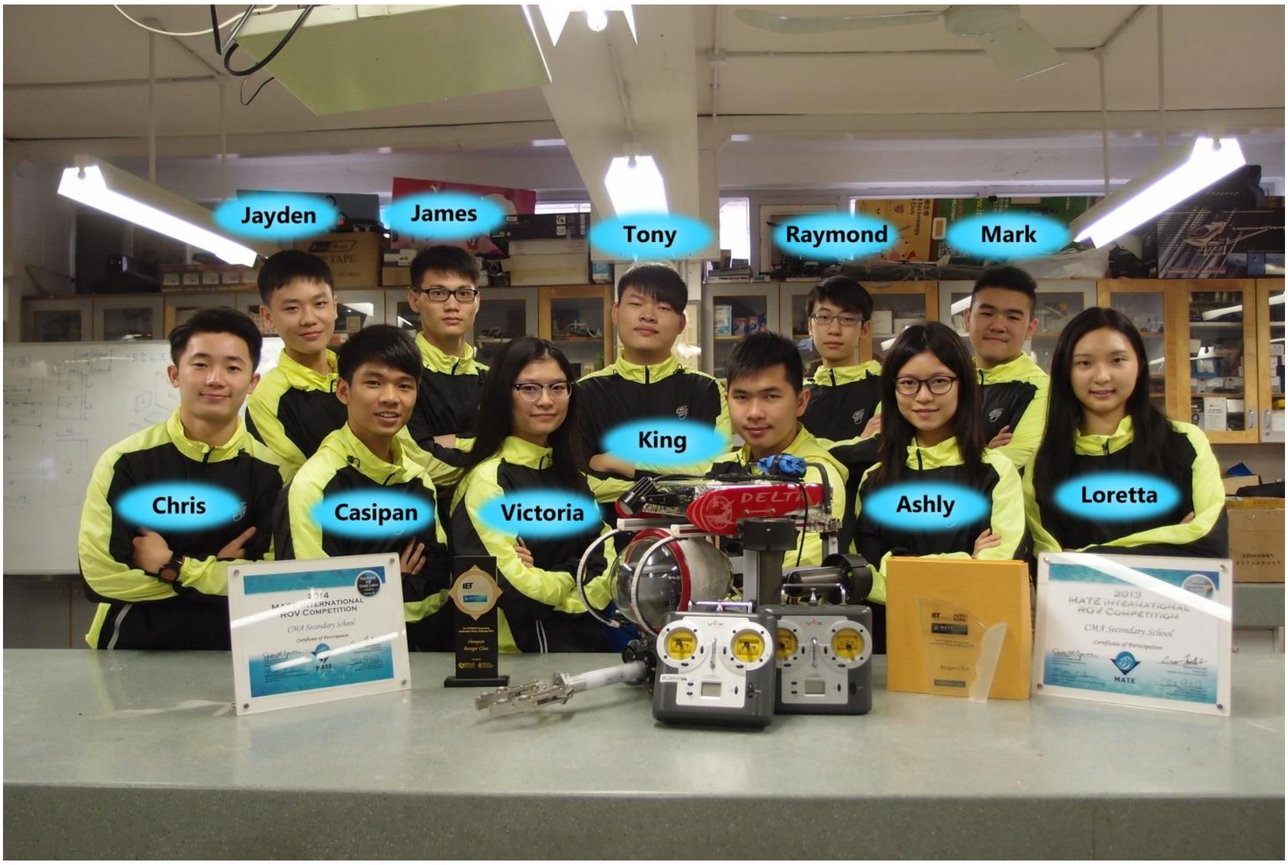

Figure 1: Team Photo of CMA Underwater Expert Ltd

A. Aim

This year, CMA Underwater Expert Ltd. focuses on achieving two objectives.

Our primary objective is to build an integrated underwater robot equipped with the latest technologies at its smallest size. We aim to keep our ROVs tiny, robust and functional. Our second objective is to pilot our professional and sophisticated ROV to accomplish all three missions and meet the requirements of the 2015 MATE ROV Competition.

The following sections devoting to frame design, control system as well as navigation system are directed not only at completing the competition, but to improve human lives in the future.

B. Design Process

In order to create an ROV which is compatible with our company's proprieties and the requirement of MATE this year, we hold a lot of meetings discussing on the design. We have listed out the techniques needed in all the missions, deficiencies of previous ROVs and discussed thoroughly during our brainstorming sessions.

1) Design the specifications of ***Delta***
2) Choosing the layout of the frame
3) Design electrical distribution housing
4) Choosing the vision system arrangement
5) Design of the control panel
6) Assembly of the ROV
7) Software development
8) Development and testing of auxiliary tools
9) Testing and troubleshooting of all systems
10) Aesthetic decoration and design

The development timeline is shown in Figure 2

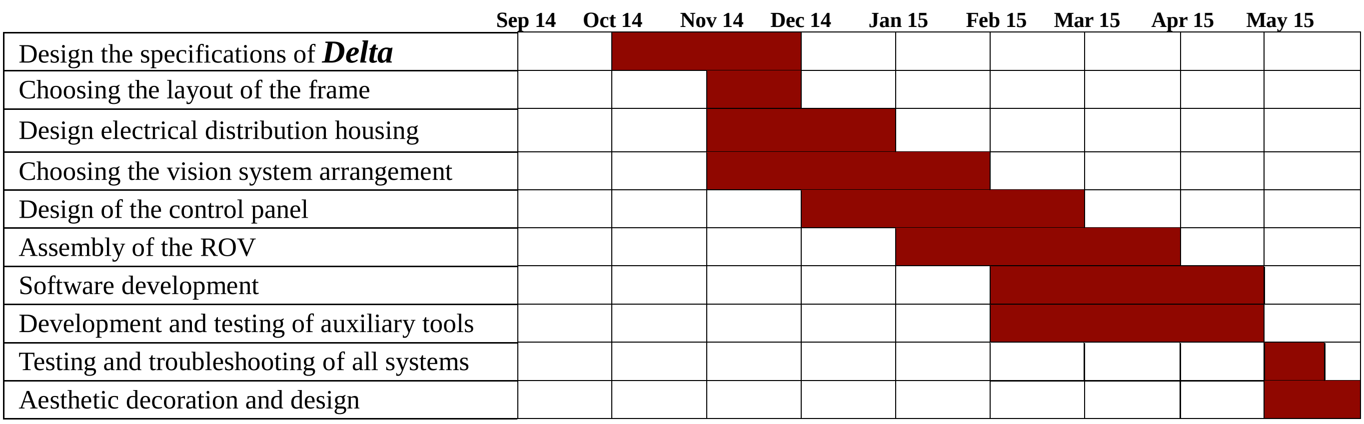

Figure 2: The development timeline

C. Overview (sketches and drafts of *Delta*)

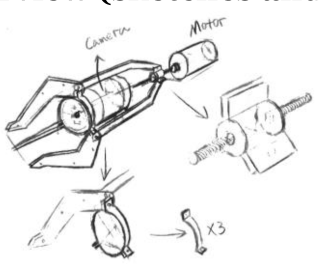

Figure 3: Concept Drawing of Manipulator

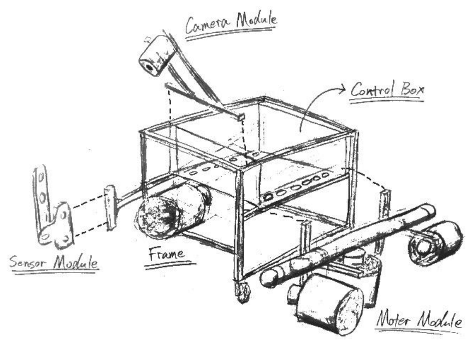

Figure 4: Concept Drawing of Delta

Once the design team has validated the concepts through sketches (as shown in Figure3 and Figure4), a detailed Computer-Aided Design and Drafting (CADD) model in either 2D or 3D, based on need, is fashioned utilizing *Corel DESIGNER* or *SketchUp*, respectively.

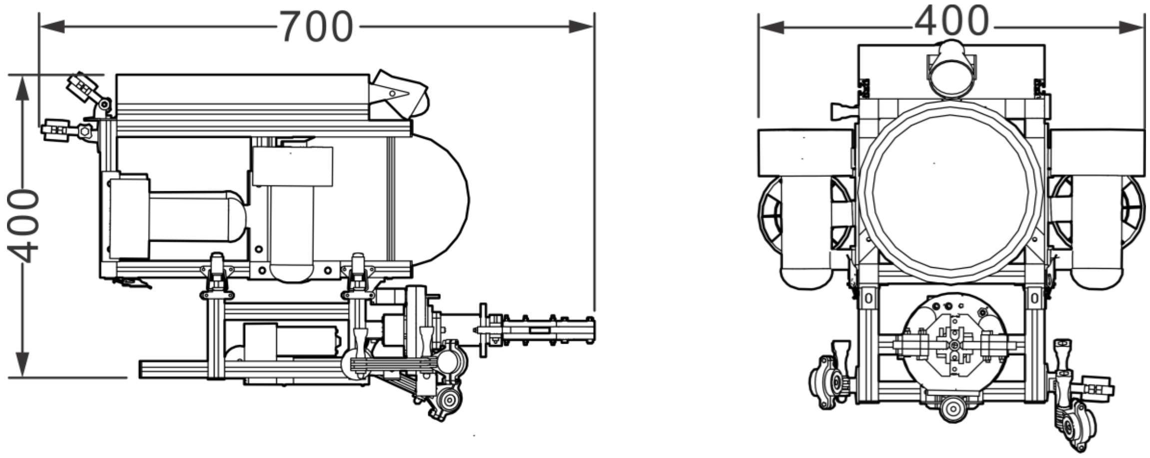

Figure 5: Drawings of ***Delta***

In order to maximize the efficiency of the design process, we use a CAD model to illustrate the ideas of our ROV, allowing our members to share and discuss freely while necessary changes are incorporated until the ultimate design is achieved.

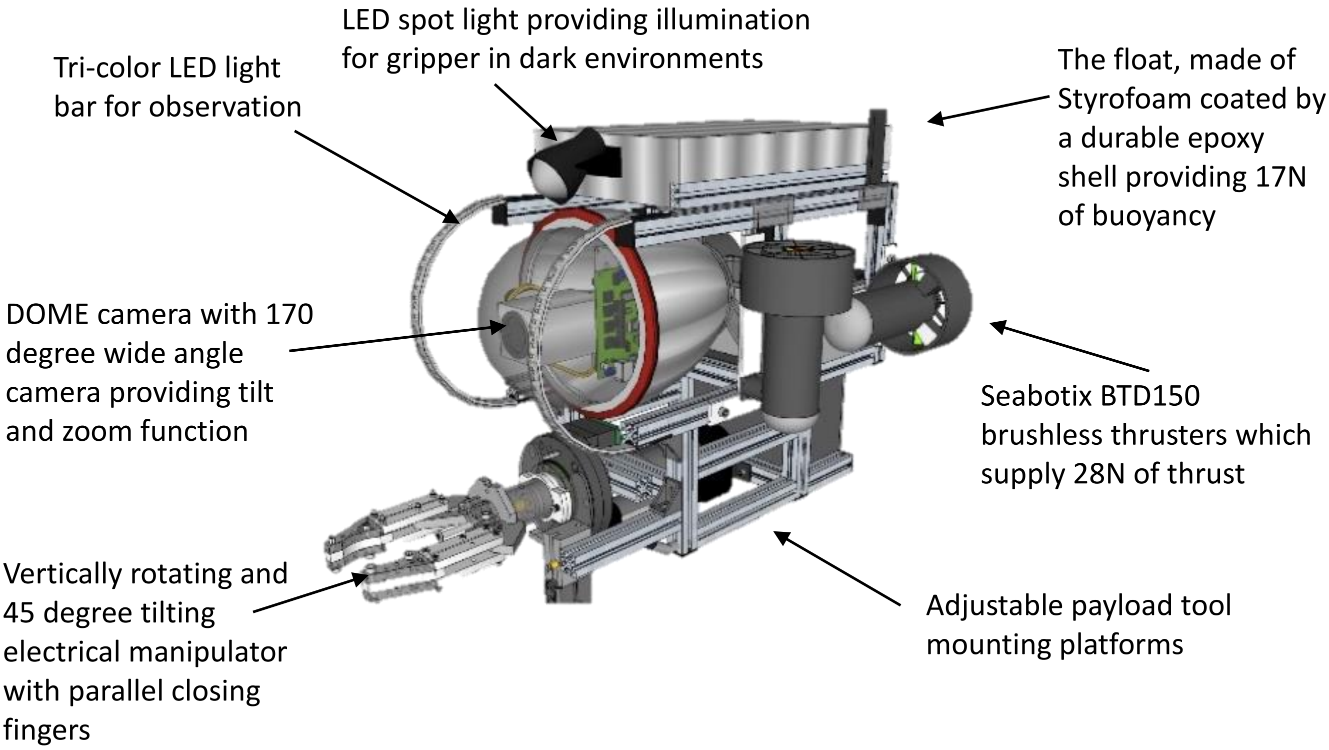

Figure 6: CAD model of ***Delta***

D. System Integration Diagram (SID)

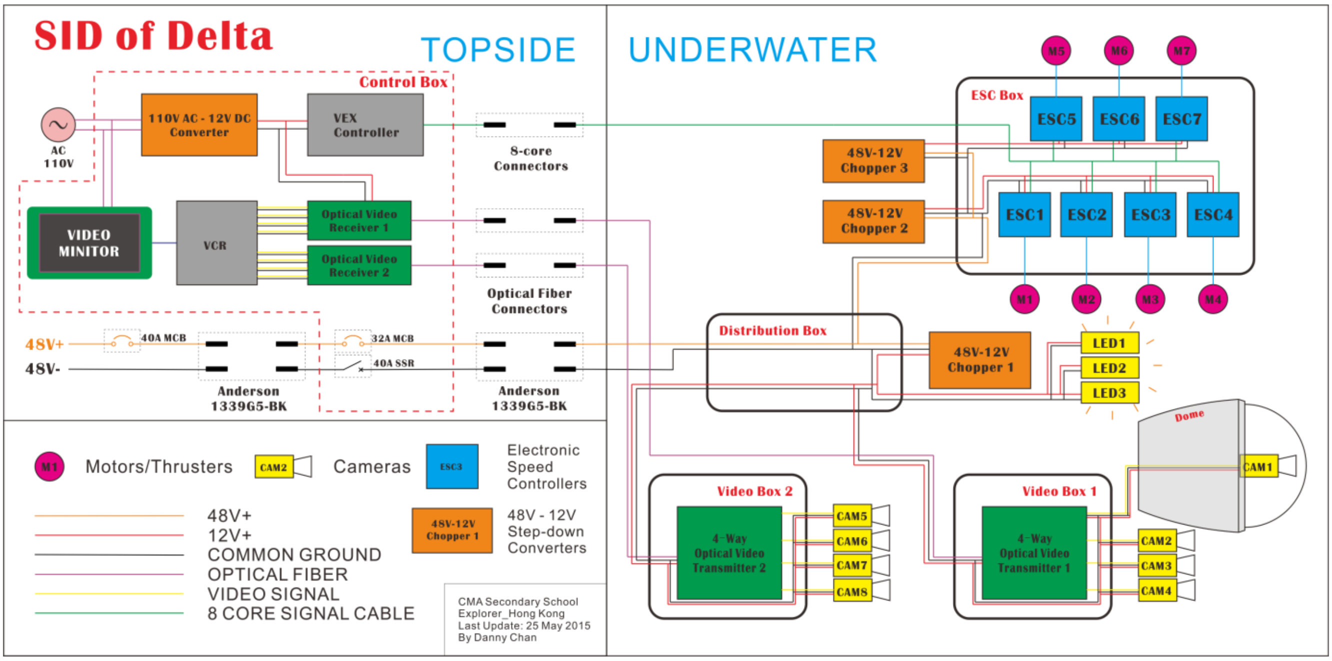

Figure 7: System Integration Diagram of ***Delta***

The two 4-way optical video transmitters send the signals from eight cameras to the topside to allow for multiple views of mission-specific accessories.

Using optical fibers to transmit camera signals is conducive to reduce interference as well as to keep ***Delta*** light and the tether thin. The control signal from VEX controller to the Electronic Speed Controllers (ESCs) are transmitted using 8-core silicon coated wires for its greatest flexibility and stability.

Three 120W 48V to 12V DC-DC converters are used to provide 12V power to the thrusters, LED lights and optical video transmitters. Power consumption of the whole system is limited by 360W which is more energy-saving compared to other similar ROVs.

E. Tether

The tether for ***Delta*** is 30 meters long consisting of one 2-core cable, one 8-core cable and 2 optical fibers. The 2-core cable is used to provide power to ***Delta*** while the 8-core cable is used to transmit signals that has been sent through the VEX controllers. As for the 2 optical fibers, they are used to transmit camera signals back to the 2 optical receivers.

Figure 8 on the right compares the differences between the tether used currently and previously. This year, we have improved the tether by reducing the numbers of cables although the cables are 3mm thicker than last year. The reason for choosing an 8-core cable instead of a CAT-5

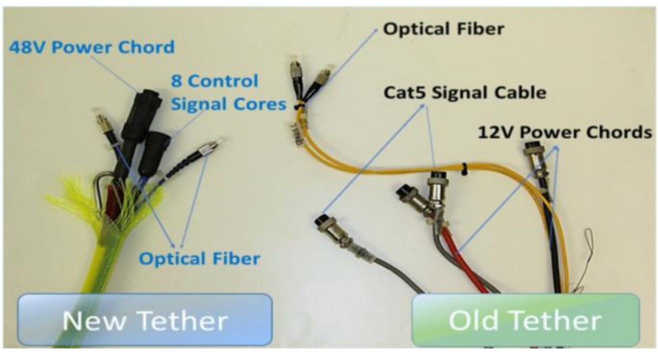

Figure 8: Comparison of the content of old and new tethers

cable is about greater flexibility. Considering that a CAT-5 cable is more fragile and we have to bear the risks of snapping if it bents too much during transportation or operation.

Two power cables are combined into one single cable for ***Delta*** in order to lose weight and reduce thickness. A 1.5mm wire is attached on the tether to pull the entire ROV back to the surface in case ***Delta*** is not functioning. The wire is also capable to pull things up to 200kg. All cables are being wrapped up by Nylon Woven Braid Wire for safety protections.

	Old tether	New tether
Diameter (mm)	12	27
Length (m)	30	30
Total weight (kg)	5	10
Weight per meter wire (kg/m)	0.33	3
Cables included	2 of 12V power	1 of 48V power
	2 of cat5 signal cable	1 of 8 pins signal cable
	1 of camera signal cable	2 of camera signal cables
Protection material	Polyethylene terephthalate	Polyethylene terephthalate

Figure 9: Data comparison between old and new tethers

F. Frame

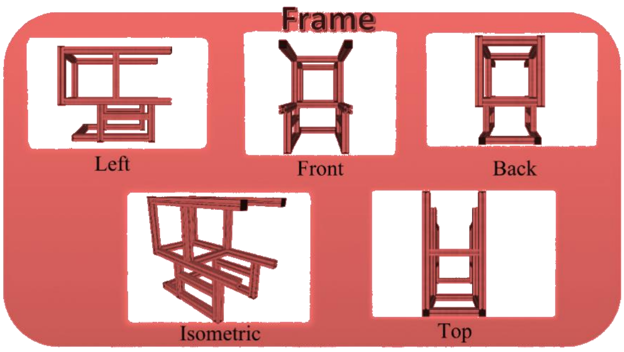

*Figure 10: Overview of the frame of **Delta***

The frame of ***Delta*** is made of 2020 Aluminum steel in the dimension of 450mm x 380mm x 400mm. Compared to other materials like iron, aluminum is rust-free and easier to be cut. Moreover, it is cheaper and easier to be installed with other mechanics or electrical components. ***Delta*** is designed to be the smallest ROV among the Explorer Class in order to conveniently pass through the 750mm x 750mm hole in the ice and conduct various tasks flexibly. On the other hand, a tiny ***Delta*** is designed due to logistic concern. By doing so, one single flight case is enough for the shipping of ***Delta*** which is considerably handy.

The open frame of ***Delta*** provides minimal obstruction and has enough space for the installation of the Electronic Speed Controllers, Optical Fiber Box, Electrical Distribution Box, and DOME camera. All electrical components have been placed at the back of the frame for convenient electrical connection from the tether. The front section houses a manipulator, 360° turntable bearing kit, an actuator, and a DOME camera for more stabilized buoyancy and the hemispheric housing aids the streamlining effect while moving in the water.

The most incredible feature of the frame of ***Delta*** is its quickly detachable mechanism. It can be separated into 2 sections within 5 seconds of time without detaching or disconnecting any other components by unlocking a few buckles. This feature enables the components for full visibility during testing and convenience repairing. According to our previous years of experience, we had to break our ROV into different parts in order to ship safely to the international competition sites. This year, the distance for shipping from Hong Kong to St John, NB is 12,496 km. Such long distance may cause damages to our ***Delta*** while travelling to Canada. Thus, a quickly detachable mechanism is designed for shipping, and to prevent any possible damages caused by the Immigration Office. Also, every sharp corners of the frame has been attached with plastic covers to prevent harm to anyone.

G. Electrical Distribution Control Panel (EDCP)

The Electrical Distribution Control Panel is the main control system for ***Delta***. It gathers the Tether Control System (TCS) on shore, communications, tether connecting to the ROV, and onboard electronics together. All the electrical components are installed in a large flight case. This makes our Electrical Distribution Control Panel to be highly integrated.

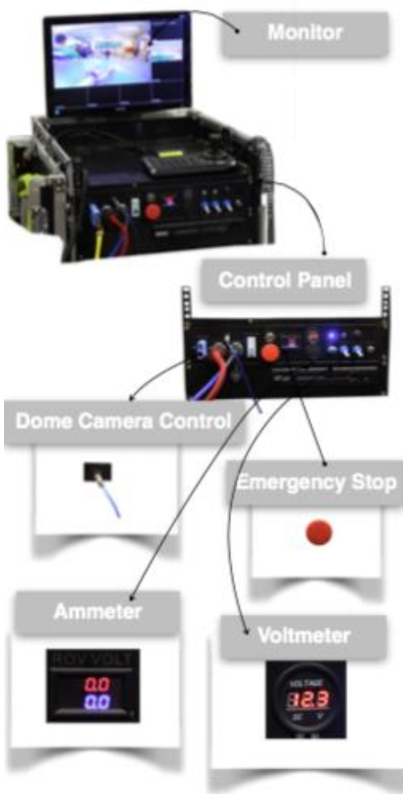

Figure 11: Features of EDCP

For safety concern, all electrical components on shore are grouped into one venue for convenient trouble-shooting. To activate ***Delta***, a 40A and a 32A circuit breaker on the TCS must be closed in order to turn on the power switch, which is a safety feature insuring no accidents happened while operating it. In addition to the circuit breaker and the main power switch, there is a power toggle button for all major networking components inside the TCU.

Two high capacity step down power regulators (48VDC to 12VDC) are used on ***Delta*** to power the embedded electrical components. Voltage and current meters are installed to allow the pilots to monitor for power issues such as discharged batteries and short circuits. Signals of the cameras are being transmitted from two optical fiber transmitters. The two optical fiber transmitters are installed on ***Delta***. Since one optical fiber transmitter can only send signals for four cameras the most, we used two optical fiber transmitters to send a total of eight cameras' signals to the EDCP Optical Fiber Receivers.

The two optical fiber receivers transfer the cameras' signals into video images. The video images are sent to the digital video recorder for grouping the video images so as to display all videos on the same monitor. This provides the pilots a full and clear picture while operating ***Delta***. Two VEX controllers are installed in the EDCP to control the thrusters for the movements of ***Delta***. The 19inch monitor is able to rise up vertically and automatically by installing an actuator and its position can be adjusted for better scanning during operation.

H. VEX Controller Kit

Our VEX Controller kit controls the 7 ESCs, which in turn controls the motions of ***Delta***, the turntable bearing kit and the performance of the manipulator. The control system consists of two 750MHz RF transmitters and one receiver remote control with two radio transmitter units and compatible receiver units. The availability of such units allows easier accommodation for future expansions of the ROV subsystems. What's worth introducing is that the VEX controller joysticks are among the small number of components purchased from commercial companies. Since VEX controller joysticks can be widely found from remote-controlled toys and models, thus the resources spent on pilot training for the operation of ROVs can be lessened.

Figure 12: VEX Robotics Transmitter

I. Electronic Speed Controllers (ESCs)

Our four SeaBotix thrusters are controlled by seven waterproofed 1060 Brushed Electronic Speed Controllers. These controllers not only give power to the thrusters, but they also give signals that have been received from the VEX Controllers for thrusters speed control. They allow operators to have a more accurate control of the direction and the moving speed of the ROV through a more effective thrusters' management. These controllers can be controlled with our VEX controllers. They are waterproofed with the cover of an acrylic plane stuck with epoxy.

Figure 14: Waterproofed box containing 7 ESCs

Figure 13: 60A Brushed ESC

J. Thrusters

Thrusters ***Delta*** is being operated with 4 strong SeaBotix BTD150 thrusters. 2 are mounted horizontally to move forward and backward and 2 are mounted vertically to rise and dive.

Each thruster provides a maximum of 28N of thrust with a sustainable thrust of 20N.

Each thruster is being mounted by cutting a kitchen board using a laser cutter machine. A protective cover has covered each thrusters for minimal obstructions to the brush, and a safety warning has also been labeled on each covers for safety issues.

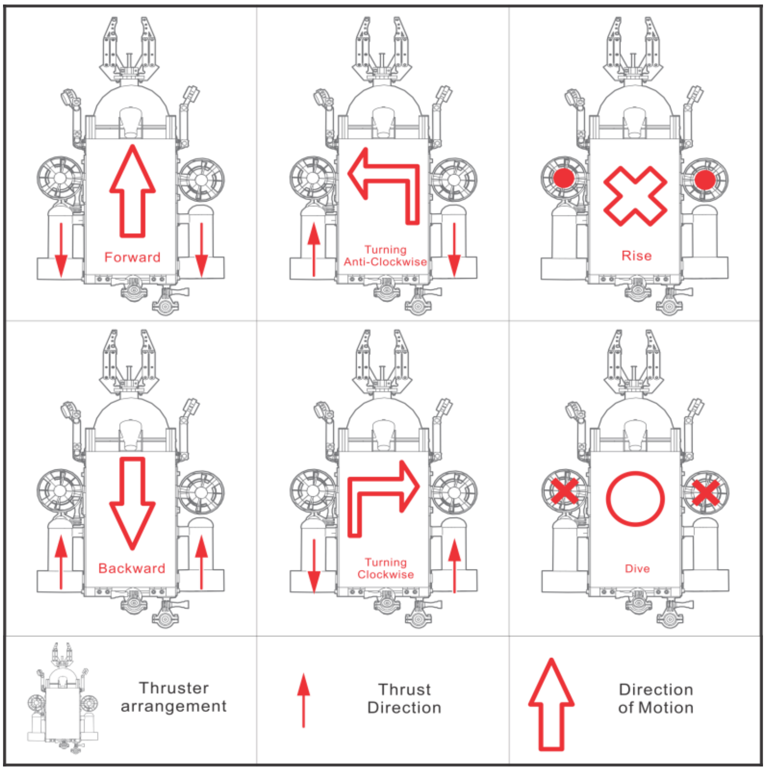

*Figure 15: Explanation of **Delta**'s propulsion system*

K. Buoyancy

Delta is outfitted with a buoyancy float system specifically designed to neutralize the ROV buoyancy. The CMA Underwater Inc. test the buoyancy float by installing it on ***Delta***, with all the components installed, then test it a mini size pool. This testing method allows ***Delta*** to have a more accuracy of buoyancy than calculation.

Figure 16: Styrofoam providing 30N of buoyancy

The weight in water of ***Delta***, before the addition of the float, was 30N. The buoyancy board has a dimension of 312mm x 186mm x 51mm, providing 30N of buoyancy, compensating for the vehicle wet weight and was installed on top of ***Delta*** to provide a better buoyancy than placing other sides of it.

Figure 17: Jayden, our CTO, checking the buoyancy of Delta

The buoyancy board is cut by a laser cutter then fiber-glassed with bandages and epoxy. Its bright yellow color represents safety to remind CMA Underwater Inc. to be careful when repairing or operating ***Delta***.

For the tether, a rope of 15mm dimension foam were attached to ensure that it maintains proper buoyancy, providing easy tether management and increasing operational stability while operation. The section of tether closest to the ROV was attached with a tether locker to avoid snagging on the ship and threatening the prosperous of the mission.

L. Software Flow

The CMA Underwater Expert Company Inc. has chosen the most accommodative software for the movement of ***Delta***, which is EasyC software, is a graphical programmer and has a great command of the software flow, to control the thrusters and manipulator through the Electronic Speed Controllers.

Before inputting the thruster values, the software can check those values to make sure they are within the safety parameters of the thrusters, and then outputs them as PWM (Pulse Width Modulation).

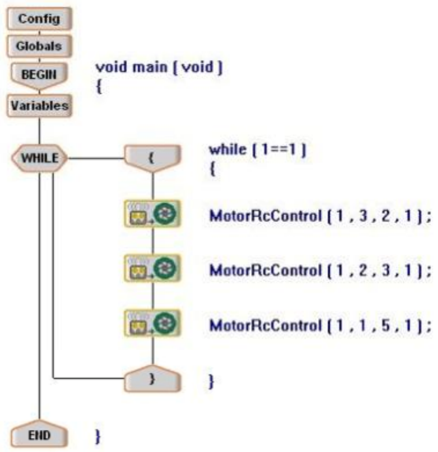

Figure 18: A graphical program used to control the manipulator, created using EasyC

The team is very familiar with its software because they have been participating VEX competition that requires to use EasyC software to play. Thus they have chosen EasyC software to operate ***Delta***.

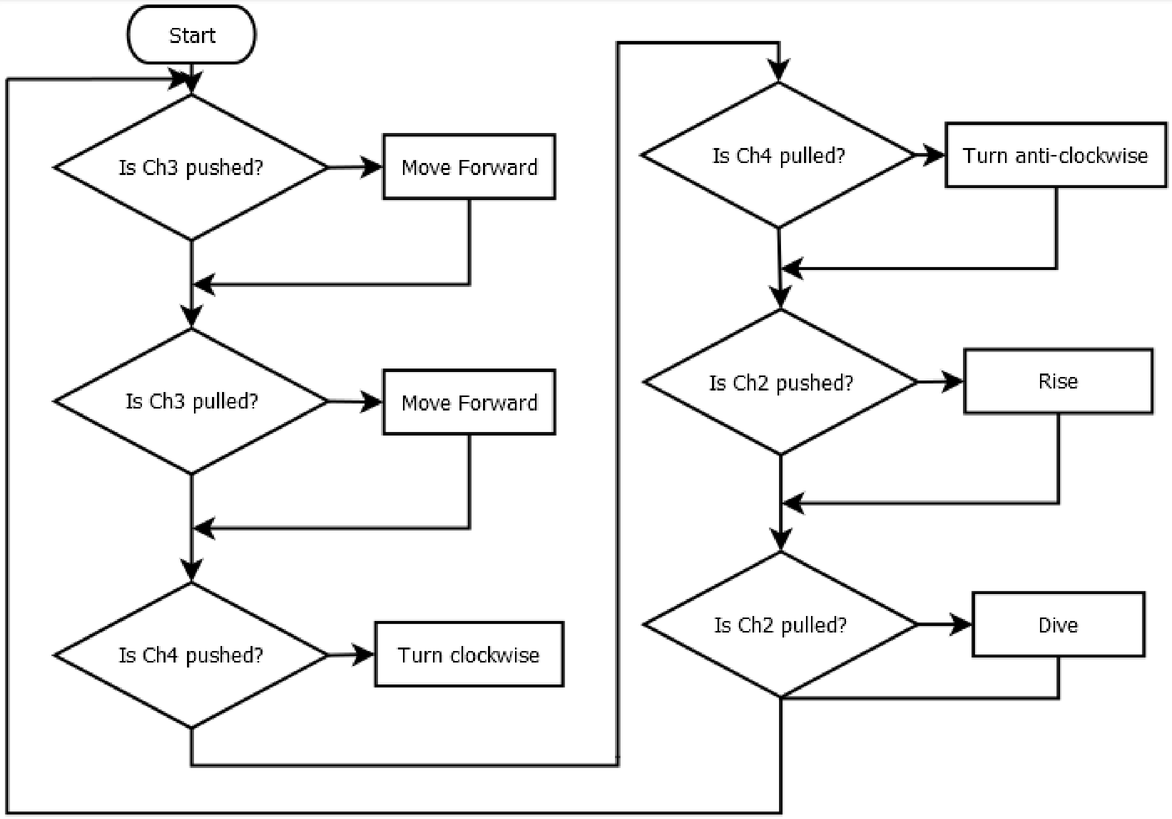

Figure 19: Program flow of movement control

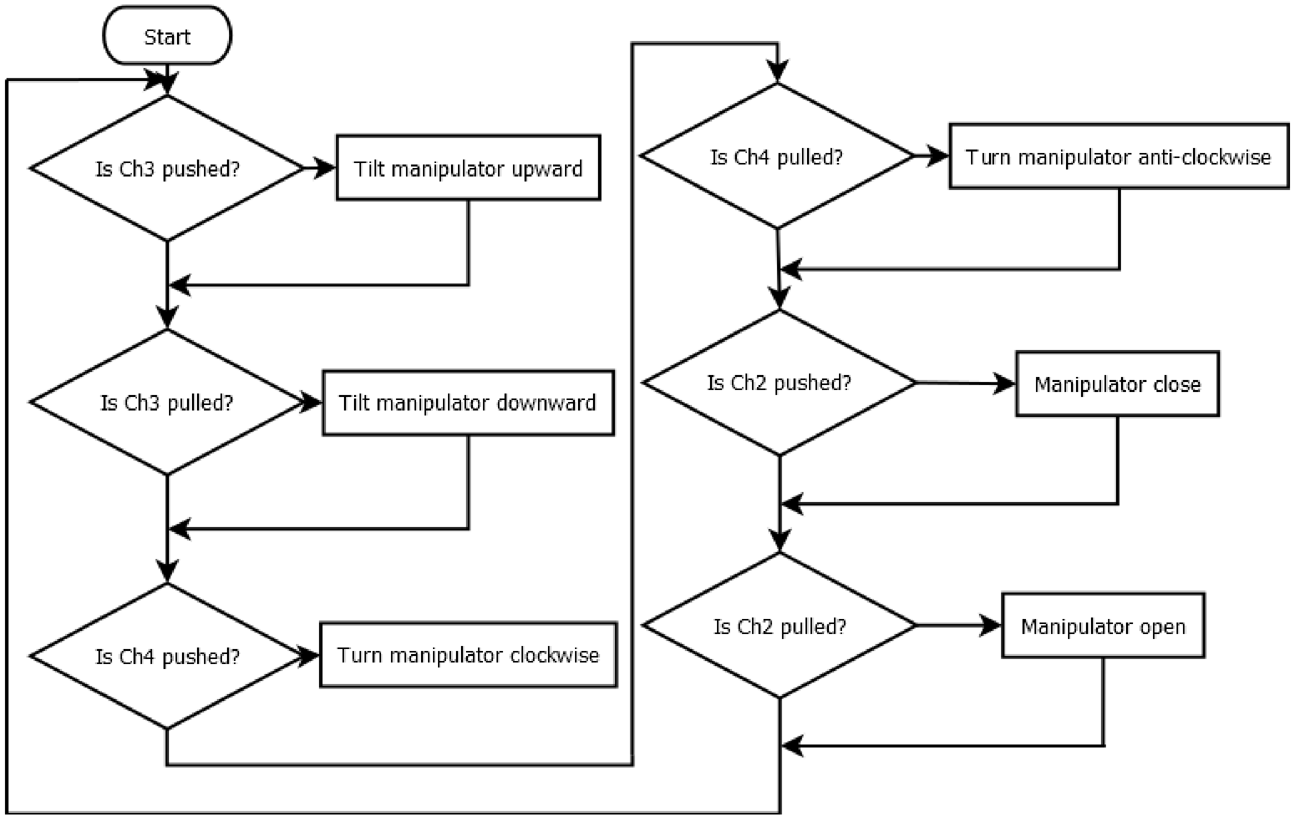

Figure 20: Program flow of manipulator control

M. Mission-specific

Cameras

Navigation greatly relies on the use of cameras. Aside from observation and identification, a lot of measurement is required for this year's missions. In the realistic context, icebergs could be in any forms.

In order to cover every possible blind spot and keep ***Delta*** steady, one DOME camera and seven additional cameras with fixed angles are attached to ***Delta*** to achieve maximum field of vision of 360°.

Considering the confusion caused by the poor visual images of the cameras last year, all cameras have been upgraded with higher definition of 720p and wider angles of 170° horizontally.

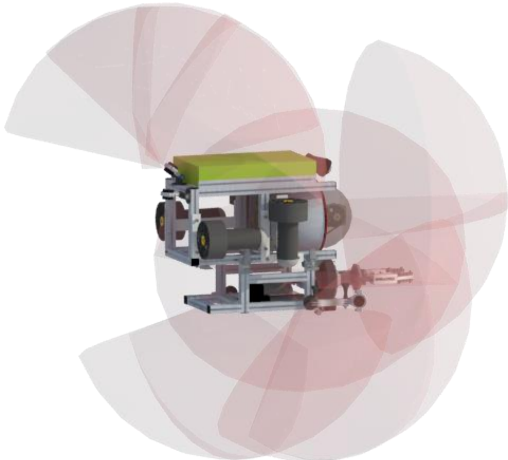

Figure 21: Simulation for possible vision of ***Delta***

DOME Camera

Delta is a cost-effective ROV that it is mostly made of authentic materials. The DOME Camera was originally a surveillance camera in a residential building. After recycling and redesigning, we turned it into a hemispheric housing with an upgraded camera placed at the front of ***Delta***. It can be remotely controlled through manipulating the control panel.

Learning from last year's experience, the DOME camera is upgraded with higher definition of 720p and zooming which helps to identify sea stars and locate the corroded section of pipeline accurately. As the main camera and component of ***Delta***, its primary function is for navigation and monitoring the manipulator so as to make sure every task is running smoothly. With its flexible vertical motion, the keel depth of the iceberg could be measured conveniently and steadily.

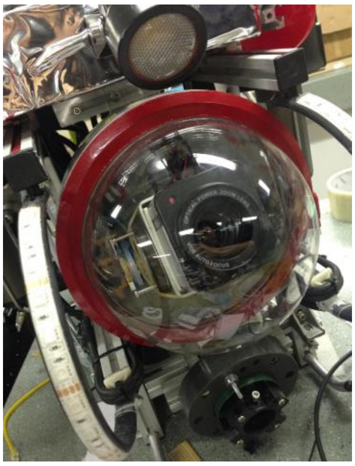

Figure 22: Overview of DOME Camera

Side Cameras

ROVs serve to suit human's convenience. All seven additional cameras are set on the side of ***Delta*** with GoPro mounts at a fixed angle. Tasks like locating samples of algae and sea urchin, identifying the species of sea stars, surveying and measuring the diameter and keel depth of the iceberg as well as inspecting the corroded section of pipeline and oil platform could be conducted efficiently without the need to turn ***Delta*** back and forth. Operation time could thus be lessened while turbulences and disruptions could be prevented for safety concern.

Figure 23: Camera testing

As mentioned, the side cameras help to conduct various tasks, let alone locating, positioning and directing. Through the cameras, signals are transmitted and received by optical fiber and turned them to DVR. For instance, the four points of the iceberg could be displayed through video which leads us to the next task. Cameras are function to monitor some of the payloads as well. The "front" cameras specifically serve for navigation and monitoring the operation of the manipulator and the "back" cameras serve to monitor the twister. Added to the above, cameras facing upward and downward could make sure the balancing and lifting of ***Delta***.

Manipulator

Delta is equipped with an electromechanical manipulator built with 12 Volts DC powered. The manipulator is an essential tool for ***Delta*** which is entirely designed by our company and utilized for multiple tasks. Under ***Delta***'s quickly detachable mechanism, the manipulator can be easily installed or removed through magnet couple.

Our manipulator is simple yet powerful. Turning the motor clockwise and anti-clockwise forces the manipulator to open and close in a parallel motion. It takes only two seconds for the manipulator to complete the whole set of opening and closing movements. This enables quicker task completion.

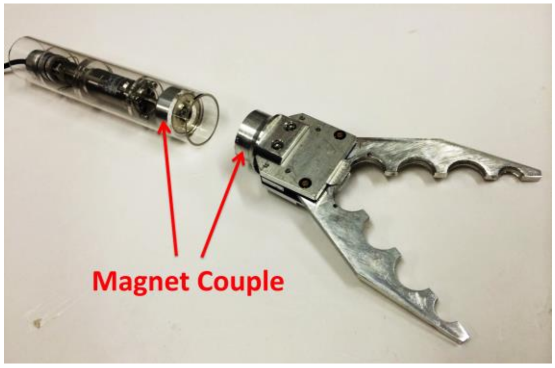

Figure 24: Overview of manipulator

A turntable bearing kit is inserted into the manipulator to allow 360° clockwise or anti-clockwise rotation. It is able to clip things up to 15kg steadily and incline 45° vertically. It is specially designed to work under extreme environment such as wavy situations with its great flexibility.

The manipulator is capable of conducting a large variety of tasks including collecting samples of sea urchin, placing devices like passive acoustic sensor, wellhead cab and hot stab, removing the U-bolt from the corroded section of pipeline. A pair of voltage sensor would be attached on the manipulator in order to test the electrical current of four distinct points from the leg of an oil platform.

Voltage Detector

A pair of iron sheet is the tool essential for detecting the electrical current of four distinct points on the leg of an oil platform. This is considered to be one of the most significant tools for it prevents the leg of an oil platform from collapsing due to galvanic corrosion.

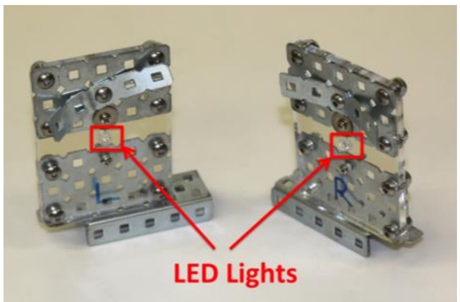

Figure 25: Voltage Detector

The voltage detector is a pair of rectangular iron conductors with LED lights. Attached on both sides of the manipulator, two test points could be detected at the same time. Whenever a failed test point where electrical current is detected, the LED lights on that particular iron sheet on, and vice versa. Using of LED lights is an impressive way to tell whether a test point is a failed or functioning one, especially under environment with low visibility.

LED Light Bars and Spotlight

Our company is aware of the unpredictable visibility underwater. In view of that, we have built our illuminating system for navigation and to prevent any inaccuracy and deviation during the process of identification and measurement.

The LED light bars composed of tri-color LED help to reflect the genuine color of any possible subsea asset and actual corrosion of pipeline. This is beneficial for marine observation and maintenance. Knowing that the color of subsea assets are more like cold color than warm color underwater which may not be their actual color, the 12V-powered LED light bars are able to adjust the proportion of the tri-color (red, blue and green) so as to compensate the difference of the color temperature to reveal the true color for accurate identification.

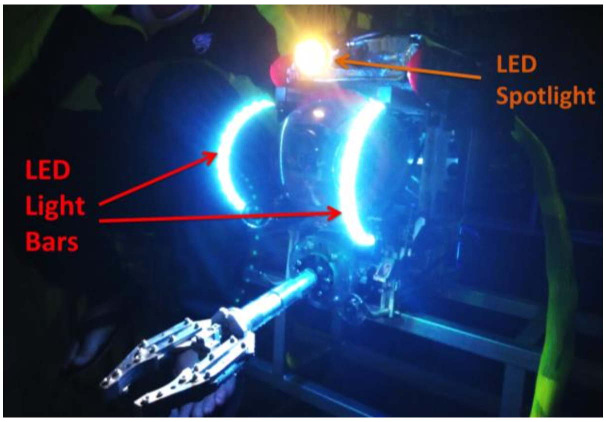

Figure 26: Illuminating system of ***Delta***

Relying on the LED light bars for complete illumination is not enough. Thinking one more step forward than other companies, we added a LED spotlight at the top front of ***Delta*** to perfect our illumination system. With the LED spot light on, the lighting can be more focused on a single object or at one direction which helps to clarify certain subsea asset or samples like sea stars, observe and confirm the corroded section of pipeline, and measure the diameter and keel depth of the iceberg.

Algae Collector

Collecting samples is vital for marine observation and researches. It is of the same importance that the collecting of samples must be done carefully without damaging them. To collect samples of algae, we have designed a triangular-shaped aluminum frame together with a metal grid covered with a net. This algae collector will be attached on the top of ***Delta*** during task. Samples of algae will be collected passively when ***Delta*** is being piloted to the underside of the ice sheet.

Figure 27: Mock test of collecting algae

Considering the protection of samples collected and the risk of increasing the weight of ***Delta***, we use a net as the cover instead of other sealed materials and make use of the standard grid size of the metal grid to collect algae at the minimum weight without damaging them.

Liftline

Liftline plays a large role in the second mission regarding subsea pipeline inspection and repair. The liftline, which is designed to be a PVC clip, simulates cutting of the corroded section of pipeline as well as transports the pipeline to the surface. Liftline is also used as a reference point for measurement such as the length of the section of corroded pipeline.

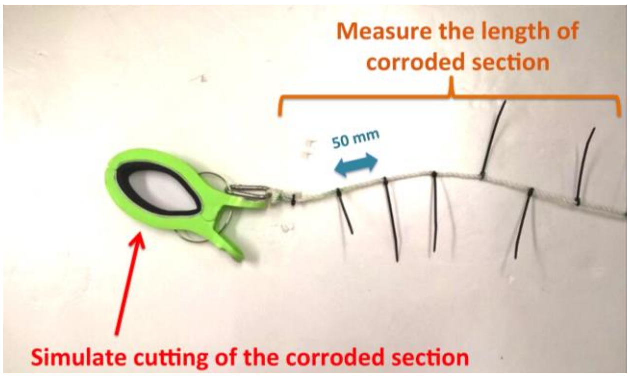

Figure 28: Overview of liftline

The additional component of liftline includes a length of ropes with 50mm intervals made by plastic straps together with 20 meters. This is useful for references of measurements.

Water Flow Sensor

Figure 29: Overview of water flow sensor

As a professional ROV, it must be capable to conduct various tasks regardless of the variation of water flow. The water flow sensor is designed to read the average water flow rate underwater. It is an environmental-friendly tool for the main body is originally a wasted water bottle. After recycling and redesigning, we added a device of an encoder inside which emits pulses for counting. When water flows through the bottle, the data will be recorded and the reading of average water flow rate will be displayed on the screen of the control panel on shore.

Valve Controller

The valve controller, which is another payload tool of ***Delta***, is made of authentic materials and entirely designed by our company. Designed purposely for turning valves underwater, the valve controller is composed of a U-grip and a tube with a 20 meters cable connected to the control panel on shore.

The motor-supported U-grip is made of PLA and built by a 3D printer. One of the sides is painted in red so as to open or close the valves accurately for 3.25times around. It is able to turn itself either clockwise or anticlockwise up to 1170°. A transparent tube made of acrylic glass with a motor inside is stuffed with grease oil to prevent water leakage.

Figure 30: Valve Controller

To make sure the valves could be completely opened or closed for safety concern, a pair of acrylic plate is added in the middle of the surface of the tube. In doing so, the manipulator can grab the valve controller at fixed point, thus stabilize and fasten the process of turning.

A. Company Safety Philosophy

Safety has always been CMA Underwater Expert Ltd.'s primary concern. We have the most rigorous safety procedures, such as, the strict safety checklist and the training section for handling or operating the ROVs or any equipment in the lab. These steps can minimal the risk for injuries and provide a safe working environment.

B. Training

Team is well-trained including the newcomers and equipped with sufficient knowledge and skills to handle and operate the ROVs.

In order to make sure everyone is familiar with the operating procedures of the ROVs or any equipment in the lab. All the members need to undertake a 4-day course with 10 lessons in total (each lesson lasts for 45 minutes) before they can actually operate the ROVs and other equipment.

Figure 31: Newcomers having safety training section, host by King and Raymond

Throughout the course, assessments and exercises were given to them. Upon the completion of the course, they have to give a brief presentation to show their understanding by presenting the operating procedures of certain device or component. On top of that, every member has to attend a safety test to raise their awareness of safety and ensure that they know how to deal with safety issues. With proper training and standard tests, we can guarantee our ROVs are controlled and operated by qualified members.

C. Safety Feature of *Delta*

Mechanical Safety

Since our mechanical engineers believe sharp edges may hurt our crew when operating the ROVs, so there is no sharp edge on ***Delta***. All concerns of ***Delta*** are protected with cover to keep our crew from possible cuts. Also, the manipulator of ***Delta*** already milled during production process.

Figure 32: Cover on sharp edge and safety labels are put up on thruster

Besides, the thrusters on ***Delta*** come with their own safety shield to prevent the contact of the blades to other materials, including the human hands. As the same time, all the moving parts, such as, thrusters are clearly labeled with hazard warning stickers.

Electrical Safety

To ensure the safety of electrical system, there is a large red emergency stop button which is located on our control panel to cut the power source from tether to ***Delta*** in case of an emergency.

Figure 33: Front side of the Electrical Distribution Control Panel

Also, we installed 2 circuit breakers. For 40A circuit breaker is placed at the beginning part of the circuit to protect the overpowering of the electrical system. For 32A circuit breaker, it is a main switch of ***Delta***.

Last but not least, in control panel are installed volt-meter and amp-meter to monitor the power source within the normal operation rank (48V- 63V). It makes sure ***Delta*** was the stable operation.

Through observing the input voltage with volt-meter, automatic shut down by circuit breakers and manually operation the emergency stop button by pilots to detect any hazard that can damage the electrical system. For Figure 34, this design achieves the highest safety standard. When facing different circumstances, this safety system is able to protect our electrical system and ***Delta***.

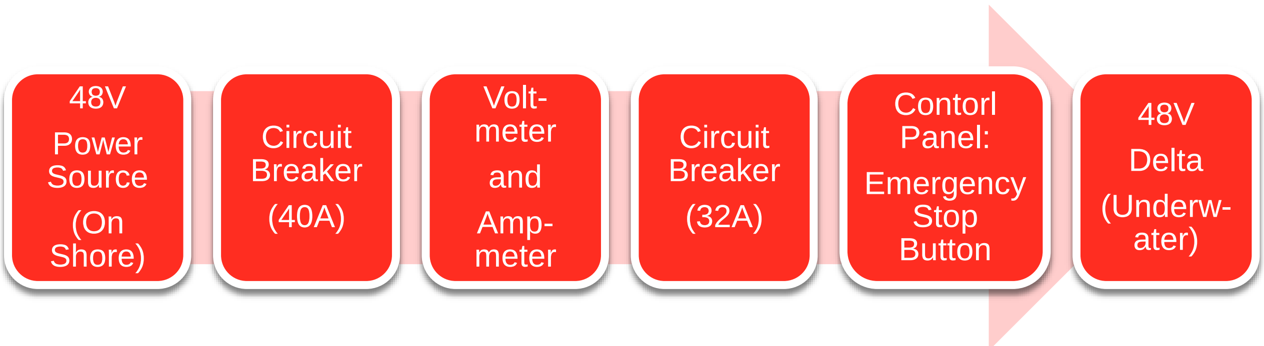

Figure 34: Safety feature of power delivery system

D. Safety Checklist

To ensure proper operation of our vehicles and safety of our crew, a rigorous checklist is designed to be completed every time before operating the ROV. The checklists are designed for the start-up, power-on, launching, in water, ROV return to surface and lost communication procedures. The presence of at least two operators and the authorization of a senior engineer are needed every time for filling in and handling the ROV.

Safety Checklist

Staff names (in full): ______________________ and ______________________

Date and time: ____

Purpose of handling: ____

Please go through every single line of this safety checklist. Put a tick in the box if the condition is met.

WARNING: Never handle the ROV unless all conditions are met.

1. Start-Up

- ☐ Safety glasses on
- ☐ Ensure the power switches and circuit breakers in Electrical Distribution Control Panel (EDCP) are 'OFF'
- ☐ Tether is properly secured to the EDCP and ROV
- ☐ All parts attached to ROV are secured
- ☐ Verify thruster shaft seals
- ☐ No conductors incorrectly touching
- ☐ Connectors are fully inserted
- ☐ Make sure the connectors matching with label
- ☐ Protect all spare connectors with dummy plugs
- ☐ Connect the power source to EDCP
- ☐ Ensure the voltmeter display within operation range (48V – 63V)

2. Power-On

- ☐ Mission commander call out "Hand Up"
- ☐ Operation technician turn on the power
- ☐ Verify the status of ROV light bar
- ☐ Verify video signal
- ☐ Mission commander call out "ROV Ready"

3. Launch

- ☐ Pilot call out "Ready to operate"
- ☐ Tether tender response "Ready"
- ☐ Pilot call out "Start to operate"

4. In Water

- ☐ Keep necessary length of tether out for avoiding tripping hazards and tether damage

5. ROV Return to Surface

- ☐ Pilot call out "ROV return to surface "
- ☐ Tether tender response "ROV back to surface"
- ☐ Pilot call out "Power down"
- ☐ Operation technician response "Power off"

6. Lost Communication

- ☐ Cycle power switch to reboot ROV
- ☐ If no communication:
  - ☐ Power down ROV
  - ☐ Reconnect with tether

In case of emergency, press the EMERGENCY STOP BUTTON on the front side of the Electrical Distribution Control Panel IMMEDIATELY.

	First Staff	Second Staff	Senior Engineer
Signature			
Name in full			
Date and time			

A. Company Structure

As a good company, it should be divide the workload clearly. Separating different department, it helps each staff fully understanding their job nature. Each department do has their own head to guide and monitor their department works. They need to report their process to CTO and CEO once a week. It assists upper management (CEO and CFO) to arrange and plan for project and company.

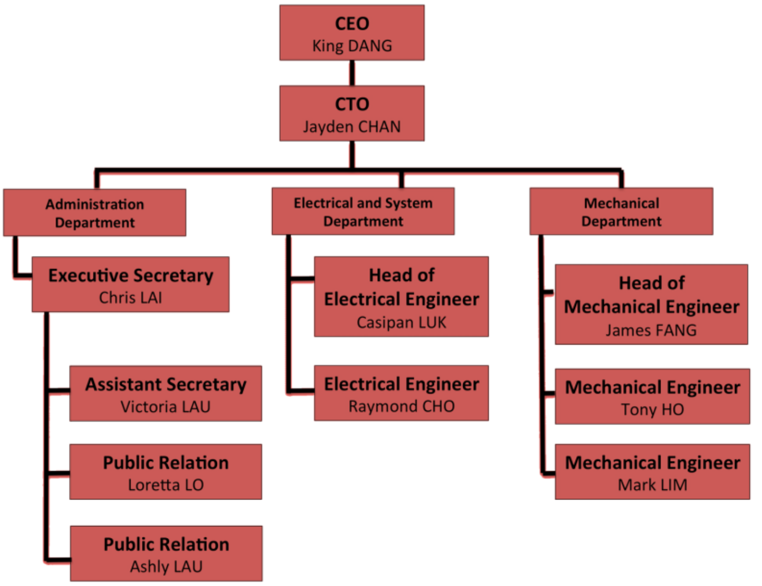

Figure 35: Hierarchy of CMA Underwater Expert Ltd.

B. Scheme of Work (Teamwork)

	Schedule							
	2014		2015					
Name	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE
Chris LAI *Executive Secretary* **Victoria LAU** *Assistant Secretary*	• Get to know ROV design • Design the safety checklist • Calculate the budget of ROV	• Research about Canada Basin	• Write the technical document • Prepare the financial report			• Receive the comment from regional contest and improve the technical document		• Trail of mission • Practice presentation
Loretta LO, Ashly LAU *Public Relation*		• Research about North Atlantic Ocean offshore of St. John's	• Write the technical report and • Design marketing display			• Receive the comment from regional contest and improve the marketing display		
Jayden CHAN *CTO* **James FANG** *Head of Mechanical Engineer*		• Design ROV structure	• Design and construct the voltage calculator, algae collector, liftline, valve controller, water flow sensor and manipulator (mission tools) • Attach the Styrofoam and thrusters on the ROV • Waterproof test			• Trail the mission before the regional contest • After the regional contest, improve the performance of all mission tools		
Tony HO, Mark LIM *Mechanical Engineer*		• Build camera						
King DANG *CEO*		• Use Sketchup to crate initial design of ROV						
Casipan LUK *Head of Electrical Engineer* **Raymond CHO** *Electrical Engineer*		• Discuss the electrical software	• Design and develop the program of control system and electrical system • Waterproof test			• After the regional contest, improve the performance of control system and electrical system		

Figure 36: Schedule of year

To make sure ***Delta*** was fully prepared for the MATE competition, a well-designed schedule ensure all the task are completed on time.

C. Budget

Category	Expenditure	Description		Qty	Cost Per Item (USD)	Total Cost (USD)
Financial Report for Delta (November 2014 - June 2015)						
ROV Parts	Aluminum Frame	20mm x 20mm	Re-used	10m	1.54	15.38
	SeaBotix BTD 150 Thruster		Re-used	4	769.23	3076.92
	Arduino		Re-used	2	12.82	25.64
	Dome		Purchased New	1	12.82	12.82
	Tether Cabling	30m (14 AWG 2-Core, 24AWG 8-Core, 2x Armored Optical Fiber, 1.5mm Wire, 15mm EPDM Foam)	Purchased New	1	3.21	192.31
	DC/DC Power Converter	48V to 12V 10A	Purchased New	3	7.69	23.08
	Camera	Viewing Angle: 170-degree	Purchased New	8	5.77	46.15
	LED Light		Purchased New	1m	6.41	6.41
	Spotlight		Purchased New	1	3.85	3.85
	Neodymium Magnet	35mm x 10mm	Purchased New	2	1.92	3.85
	Aluminum Plate	6mm	Purchased New	2	3.21	6.41
	GoPro Mount		Purchased New	6	4.49	26.92
	Actuator		Purchased New	2	19.23	38.46
	Sealed Connector		Purchased New	32	2.56	82.05
	Aluminum Box		Purchased New	4	7.69	30.77
	Optical Video Receiver		Purchased New	2	16.03	32.05
	Electronic Speed Controller		Purchased New	7	19.23	134.62
	Distribution Box		Purchased New	2	51.28	102.56
	Mission Tool	Voltage Calculator, Algae Collector, Liftline, Valve Controller, Water Flow Sensor	Purchased New	N/A	128.21	128.21
Electrical Distribution Control Panel	Flight Case		Re-used	1	192.31	192.31
	VEX Contoroller Kit		Re-used	2	205.13	410.26
	Control Box		Purchased New	1	256.41	256.41
	Optical Video Transmitter		Purchased New	2	16.03	32.05
	LCD Monitor	20"	Purchased New	1	141.03	141.03
	AC-DC Converter	110V AC to 12V DC	Purchased New	1	12.82	12.82
	4Channel Network Video Recorder		Purchased New	2	32.05	64.10
	Minerature Circuit Breaker	32A DC Type	Purchased New	1	1.28	1.28
	Amp Meter	50A Max	Purchased New	1	2.56	2.56
	Volt Meter	100V Max	Purchased New	1	2.56	2.56
	Miscellaneous Components	LED Signal Lights, Switches, Wires, Connentors	Purchased New	1	12.82	12.82
Services	Laser Cutter	Electronic Speed Controller, Manipulator, Electrical Distribution Control Panel	Donated	N/A	769.23	769.23
	Miller	Manipulator, Dome	Donated	N/A	128.21	128.21
	Lathe	Manipulator, Dome	Donated	N/A	256.41	256.41
Travel	Air Ticket		Purchased New	15	1282.05	19230.77
	Accommodation		Purchased New	11	354.10	3895.77
	Logistic expense of ROV (Estimated)	From Hong Kong to Canada	Purchased New	1	1538.46	1538.46
Miscellaneous	Consumables	Sand Paper, Glue, Drill Bits, Epoxy, Solder, Saw Blades	Purchased New	N/A	128.21	128.21
	Construction for Small Water Tank	20cm x 20cm Aluminum Truss	Purchased New	80m	3.85	307.69
	T-Shirts (Estimated)		Purchased New	21	19.23	403.85
	Printing (Estimated)		Purchased New	N/A	64.10	64.10
	Souvenir (Estimated)		Purchased New	N/A	128.21	128.21

Total Expenses of ths year in USD			31967.56
ROV Total Cost (ROV Cost, Electrical Distribution Control Panel, Services, Consumables) in USD		6398.72	

This year, funding of CMA Underwater Expert Ltd. comes from CMA Secondary School, it has USD32,000. Also, there are the donations of services and equipment from CMA Design and Applies Technology Club. The total cost for ROV components parts and services at USD6,398.72. 4 SeaBotix thrusters and 2 sets of VEC controllers are almost half of the overall ROV costs. For remaining monetary resource, we spend on improving the functionality of DETLA, traveling and miscellaneous expense. The total expense of this project is USD31,967.56. The team, together with its supervisors and mentors, has contributed an approximate 7,100 hours on the project.

Conclusion

A. Challenges

Technical

This year, our main objective is to accomplish the missions successfully and smoothly. We aim to perfect our design to be small, powerful and functional. One of the missions is conducted in the flume tank where a constant current of up to 0.25 meters per second will flow. The biggest challenge for the company is to overcome the water resistance brought by the square design of the ROV. To help tackle this, our company has come up with various alternative designs. We have been using Autodesk Flow Design to help simulate the performance of the ROV underwater and we keep refining and improving the design to improve the performance in reducing water resistance.

Using the data analysis provided by Autodesk Flow Design, we are able to conduct numerous tests, experiments and refinements until the ultimate design, ***Delta***, comes to place. Our robust ***Delta*** is now proved to be small but precise, simple but powerful, and able to work efficiently with variable water flow.

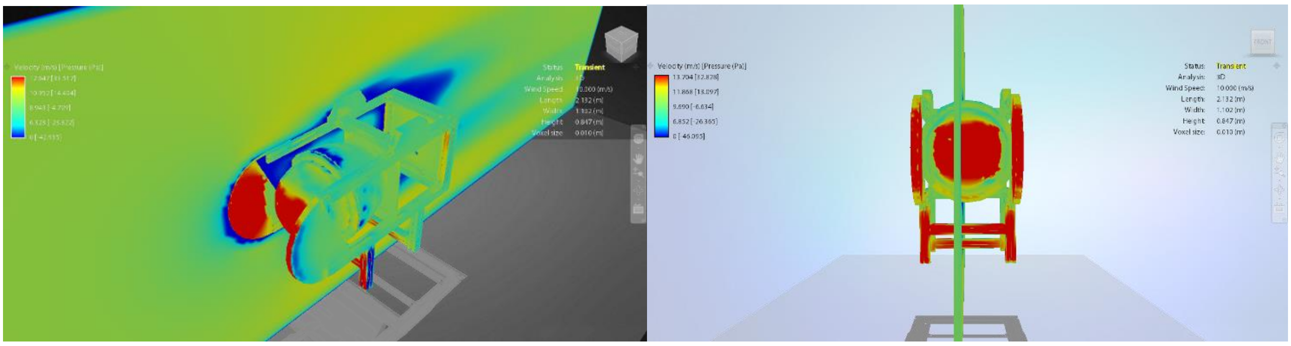

Figure 37: Simulation of the design of the ROV

Non-technical

The lack of pool trial is our biggest non-technical challenge this year. In packed countries like Hong Kong, it is very difficult for us to borrow an empty swimming pool for trials, especially during the peak season. It is common for people in Hong Kong to think that the testing of the ROV may put the people who are swimming in the pool at risks. As a result, it is almost impossible to borrow any public swimming pool under the government. Unlike the University students who have their own private pools for trials and tests, we are unable to test our ROV in a formal swimming pool. In fact, as a local student, we cannot afford the renting of a whole private swimming pool at clubhouse as well.

Figure 38: Water test in small water tank

However, we are convinced that preparation beforehand is of great importance. As a result, we built a small water tank at campus and did the small scale of trials at night. Although we cannot conduct the complete tasks due to the limitation of the size of the tank, we are still able to test the waterproofing of the components of ***Delta***.

B. Troubleshooting Technique

The role of cameras is crucial for this year's competition. There are a number of tasks requiring ***Delta*** to read data, identify samples and measure values in all three missions. Added to the above, cameras help to monitor the surroundings so that ***Delta*** can orientate itself flexibly undersea. As a result, we designed a total of eight cameras to perform different functions. Most importantly, we use the mount of GoPro to overcome the limitation of the viewing angles.

Another challenge we faced is the change of voltage. This is our first year participating the Explorer Class in the MATE competition. It requires more complex and advanced technological skills and knowledge than Ranger Class. We need to make use of the chopper to convert the voltage from 12V to either 48V or 5V in order to complete the tasks.

C. Lessons Learnt

While working on the project, we have obtained and improved upon a variety of skills in mechanics, engineering, electronics and programming. Teamwork provides an invaluable experience that could not be taught in class.

A major triumph shared by the team is the use of optical fiber. We had difficulties in transmitting clear visual images last year. Using optical fiber instead of four coaxial cables helps to solve the problem as well as to stabilize the transmitting signal. With clearer visual images, a better quality of the underwater video could be produced which is a huge advantage for ***Delta*** to conduct different tasks flexibly and identify different samples easily.

We have built up a strong team spirit and interpersonal skills in this journey. The creation of the sophisticated ***Delta*** requires countless of time and efforts. As a result, communication and cooperation between teammates is important at every stage of production. We learned to accept others' opinions and listen to others' ideas. Moreover, we are taught to give positive encouragements as well as objective comments in order to perfect our products. When our mechanical engineer was working on the design of ***Delta***, he listened to the advice of others that sharp edges should be avoided. Thus, he redesigned the appearance of ***Delta*** and became more considerate on detailed parts. We seek advices from supervisors and think of alternatives whenever we face difficulties. Throughout the designing process, we have created a more and more harmonious working environment where everyone is willing to work with others and to respect each other.

D. Future Improvement

Although it was such a great achievement building up a sophisticated ***Delta*** with high efficiency and quick detachable mechanism, ***Delta*** can be further improved in the future:

Constructing an interface to computerize every movement of ***Delta*** and to keep records of the readings is useful for future researches and developments of ROVs. Also, it is crucial for marine observation and maintenance with an interface since it helps to record the tracks and readings of ***Delta***. For example, the video recorded through the cameras displaying subsea asset and icebergs could be recorded instantly for future studies. It is much easier and more convenient to chase back the history or check up with the previous data of the ROV for further improvements as well.

In spite of the addition of an interface, there is room for improvements for staff development and mutual communication as well. Everyone in the team has his / her own duty and responsibility. As new members joined the team this year, senior staff is supposed to take care of the junior staff by explaining the company structure, passing on technical knowledge and skills as well as assigning different tasks to them. However, there maybe insufficient time for senior staff to meet with the juniors regularly. As we all know, communication is very important for cooperation and synchronization of work at this stage. Therefore, improving the mutual communication and interaction is conducive to the working process and the staff development as a whole.

E. Reflection

This year, our 7-student team is injected with the new blood of 4 year-10 students. Knowing that it is a great experience participating in such an international and professional competition, we are very enthusiastic about learning advanced technical skills and gaining more knowledge about marine conservation. We make use of this opportunity to build up stronger socializing and interpersonal skills through working with people of different age groups or countries as well.

Victoria, Assistant Secretary (Grade 10):

"As a newcomer, I barely know how to help out the team. Thankfully, our teammates are very helpful and friendly that they are really patient and willing to answer my questions. Frankly speaking, I was quite shy at the beginning, but I learned to ask for help and work with others as time goes by. I realize cooperation and the division of work are very important in a team. Everyone has his own duty and responsibility and this is how we make things work. I really appreciate the great passion and enthusiasm from the senior teammates and I love the heartwarming atmosphere here. We are encouraged to apply what we have learned into the project. Being one of the female representatives, I am glad to be part of the team and I am delighted to make contribution to the whole team!"

Figure 39: (Right Two) Jayden participating in the International MATE Competition held in Alpena, United States in June 2014

Jayden, CTO (Grade 9):

"It is always pleasant to see new members joining us to take part in the MATE competition. I hope they can benefit from it and enjoy it as part of their life journeys. I am sure this experience would definitely broaden their horizons and show them the significance and importance of teamwork. Sometimes we rely on instant online platforms like Facebook and Whatsapp to communicate and to catch up with others' working process. We hold discussions and make concerted decisions together. As a senior member in the team, I am excited to share my ideas to the junior members and pass on different skills and knowledge to them. "

King, CEO (Grade 12):

"Although I have been working in the team and joining the MATE competition for 6 years, I regard every year's competition as a new challenge. I enjoy overcoming difficulties and challenges with my teammates and I treasure the time cooperating with them. During the design process, we have acquired new knowledge and built up a strong partnership. I am glad to see that my fellow teammates are able to trust and work along well with each other. This is the key to a good working atmosphere which is beneficial to the production of ROVs. This year has been a tough one since I have to handle both the competition and the public examination at the same time. Meanwhile, I never forget my obligation as a CEO that I am not only responsible to nurture junior teammates but also promote robotics to the community. I hold a robotics workshop at a college in Macau every weekend. I believe this could raise more public concern and let more people to know about robotics technology. I also help the organizer of Hong Kong Regional ROV contest to design a leaflet in last year to let more people understand the philosophy of the competition.

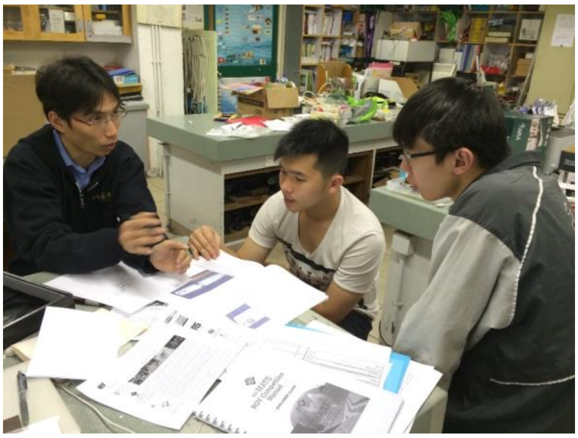

Figure 40: (From Right to Left) Raymond, King and supervisor Mr. Cheung Man Yuen discussing the mission strategies

Winning the chance to participate in this competition means a lot to me. Learning is a lifelong journey. As we are all living in a world highly relies on technologies, we should never stop developing and designing products to improve human lives. I am grateful for what the competition has brought us, including the technical knowledge, the learning motivation and the joy of leading my team to strive for excellence."

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G. Acknowledgement

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- Crystal WONG, Danny CHAN, Kimberly POON, Queenie YEUNG, Seth LEUNG – our mentors, share their valuable experiences in pervious MATE International ROV Competition to help us improve in technical and non-technical skills

MATE International ROV Competition Organizer

IET / MATE Underwater Robot Challenge 2015 Organizer