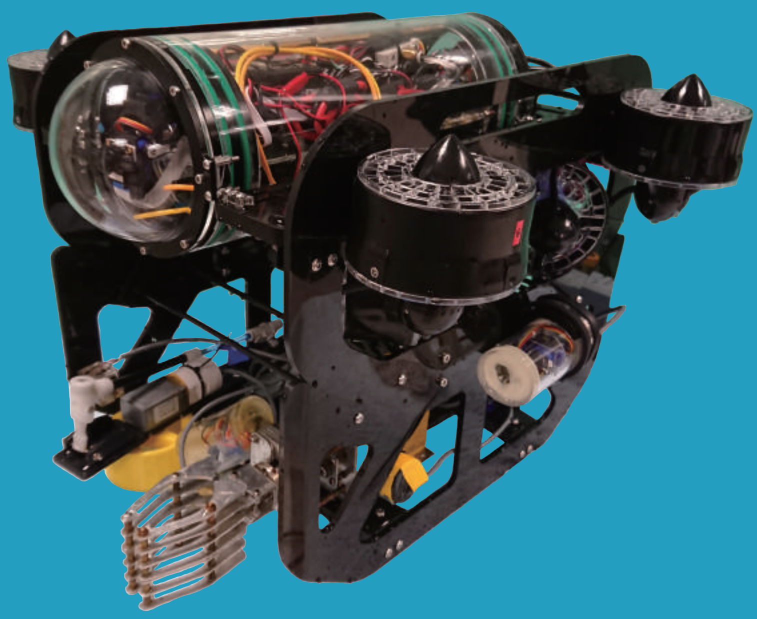
THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

UPrising

Upstream



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1. Abstract

In response to the request of the MATE Center and the Applied Physics Laboratory at the University of Washington, this proposal is presented by the Uprising Incorporation (Uprising Inc.) for a remotely Operated Vehicle (ROV) for tasks related to aircraft, earthquakes and energy. Our ROV, *Upstream*, is capable to return the debris and the engine of the aircraft from the underwater wreckage back to water surface, collecting seismograph data from the underwater device, and installing a tidal turbine in the optimum location underwater.

Uprising Inc. has been developing ROVs for the past 5 years. The company's team of 15 employees is a group of multidisciplinary specialists in engineering, software, and project management. Upstream is a product of 4500 person-hours and it is a major upgrade from our previous ROVs especially in the waterproof method and control mechanism. Upstream takes the advantage of integrating the propulsion system, control system and vision system into a compact device. The shape and frame of Upstream include some streamlined design to reduce the water friction. The dimensions and weight of Upstream have been reduced significantly. "ArduSub" is adopted as the control system because of its extensive capabilities in improving the stability of the ROV while carrying out tasks underwater.

This documentation describes the design and development process that makes Upstream the most suitable ROV to meet the requirements as stated in the Request for Proposals (RFP).

Figure 1. Company photo – Uprising Inc.
From Left to Right: Candace, Ryan, Vanessa, Owen, Albert, Paul, Ray, Sum, June, Dickie, Edison, JC, Louis, Henry, Jerry

2. Design Rationale

A. Design Evolution

During the past few years, we have built 4 different ROVs for different purposes. Considering both economic and environmental aspects, we think that parts and components should be able to reuse as much as possible. Therefore, this year we have added the interchangeability feature into our design rationale. Our customized frame not only designed for easy installation and service but also design to be interchangeable. The frame is divided into two layers. The upper layer hosts the electronics and propulsion system and the bottom layer is for tasks specific tools that can be changed easily to satisfy different requirements. With all the electronics and propulsion system in the upper layer, user can just use the upper layer as a ROV on its own.

The interchangeable design rationale not only can be shown through the design of the frame but also be reflected from different waterproof methods applied. For the control and electrical system, these are put inside the waterproof chamber for easy maintenance. For the actuator system, for control motors used in tasks related tools, we have used epoxy to seal the components so it can be changed in a short period of time.

User experience is also what we valued. From the feedbacks collected from pilots of older version of ROV, maintaining the ROV in a stable state is crucial for carrying tasks underwater. Therefore, we have upgraded our control system and rewrite the software to improve the controllability and stability of the ROV. Which can help the pilot to finish various tasks in a shorter time.

B. Mechanical Design

Frame

The frame of the ROV must be rigid and light as it provides the space to host all components. Upstream's frame, as shown in Figure 2, is mainly made of High-density polyethylene (HDPE) and joined with carbon fiber tubes. The frame consists of two layers: core part and actuator part. Core part is the upper layer and it is used to host the electronic chamber and thrusters. Actuator part, the bottom layer, is an individual and interchangeable structure designed to support tools for different tasks. The HDPE sheet was designed by our company and fabricated with Computer Numerical Control (CNC) system by a manufacturing company.

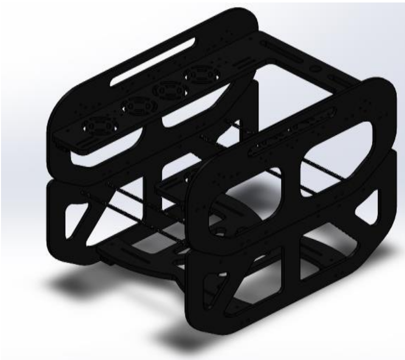

Figure 2. Frame of Upstream

Comparing to the aluminum frame that we used previously, HDPE is selected because of higher strength-to-density ratio, better loading capacity and chemical resistant. Material with high strength is needed to withstand mechanical loading. A lighter material is also preferred as a lower weight could have a larger buoyancy as well as easier to transport. The weight of the HDPE frame is less than 1 kg in air and is much lighter than the aluminum frame used in the older ROV.

The new design is employed also due to the low flexibility and low portability of our previous ROVs. With a replaceable bottom layer, Upstream can be configured into different forms, such as including a battery pack in the lower layer and becomes an autonomous ROV. Therefore, re-using either the core part or bottom layer of the frame in the future is possible.

Propulsion System

Eight thrusters are used to control both transversal and rotational motion of the ROV. Blue Robotics T200 [4] is selected due to its reasonable cost and great performance. The propulsion system consists of four horizontal thrusters in a vector configuration and four vertical thrusters. Therefore, the system allowed Upstream to maneuver with six degrees of freedom in the field as shown in Figure 3 and it also maximizes both propulsion force and torque. Assuming the forces produced by the four propellers are identical, by calculation, the angle of each motor should set at 45° to optimize both resultant force and torque.

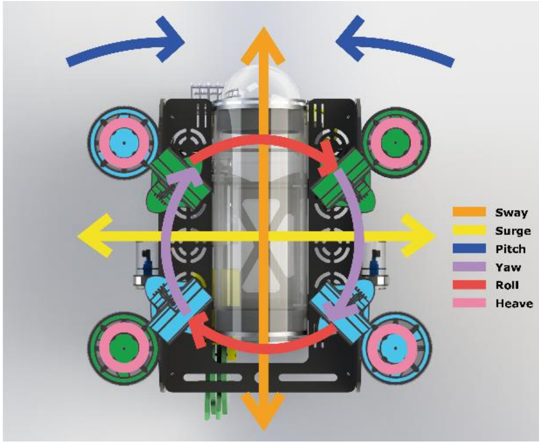

Figure 3. Six degrees of freedom (Top view)

Buoyancy

To maintain the stability of Upstream, neutrally buoyant is important and it is achieved by using PU Foam as the buoyancy material. PU Foam is a great material for buoyancy due to its low water absorption rate and high resistance to compression. Furthermore, PU foam is placed at the top of the frame which allows the center of mass of Upstream inline vertically with its center of buoyancy.

Electronic Chamber

Main electronic components are housed inside a Poly-methyl-methacrylate (acrylic) tube. Both ends of the 5mm-thick acrylic chamber used double layer O-ring as shown in Figure 4 to seal up instead of using epoxy. Electrical components are the core of the ROV and may need replacement if components fail. Fixing all components inside the chamber is the most suitable method and maintenance of the electronic components could undergo easily because the tube can be opened by simply unplug the end of the tube.

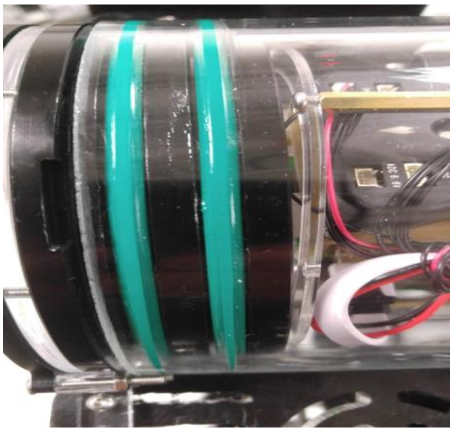

Figure 4. Double layer O-ring

Camera Tube

Figure 5. Rotatable Camera

Upstream's camera system is housed inside a Poly-methyl-methacrylate (acrylic) tube as shown in Figure 5. Both ends of the tube were sealed with a laser cut-acrylic cap by using epoxy. 3mm-thick acrylic was chosen as the material of the tube to make sure the camera system could operate under high water pressure. Acrylic was selected instead of polycarbonate because acrylic has the highest transparency of light (92%) in all types of plastic. Also, the price of acrylic is lower than polycarbonate. In addition, 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 Uprising Inc., material with hazardous chemical is prohibited in the whole design of Upstream.

Waterproofing

Most of the electronic components of Upstream are housed inside the Acrylic chamber, while the Bluetooth and Wi-Fi system of Upstream are sealed with epoxy, as shown in Figure 6, as it is highly reliable for waterproofing of electronic components proved from previous years' experience. Since epoxy excels in resisting corrosion, conducting heat, insulating electricity and having a great compressive strength which make using epoxy a perfect method for waterproofing. Its transparency also favors us when monitoring the LED signal of the components. For movable parts that cannot be potted, biodegradable grease was filled to provide viscosity for the gear to move smoothly underwater. For DC motors, a box used to protect the motor was glued with epoxy and attached to the gearbox, and the exposed gearbox was filled with biodegradable grease.

Figure 6. Bluetooth module shielded with epoxy

Uprising has tested different brands of epoxy to select the most suitable epoxy that can provide the strength and toughness, refer to Figure 7 for the experiment result. Epoxy B was selected, as it provides balance between strength and toughness along with a reasonable price for our large demand.

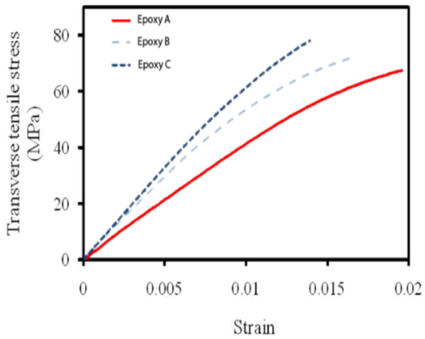

Figure 7. Plot for transverse stress against strain among 3 different epoxy

C. Electrical & Electronic Design

The electrical and electronic system provides power, control and communication for the ROV, as shown in Electrical SID (refer to Appendix A). The electrical system mainly consists of two 12V 56A DC-DC converters and distributes power to the electronic and propulsion system. The electronic system includes a Raspberry Pi and three subsystems which are control system, camera system and actuator system respectively. We put both cameras and actuators subsystems outside the waterproof chamber and the configuration inside the chamber is shown in Figure 8 and 9. The actuator subsystem is responsible for controlling various motors used in the grippers and the gas pump.

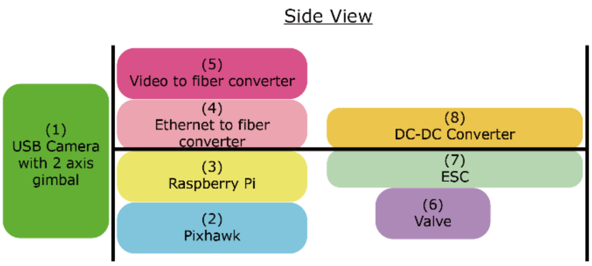

Figure 8. Electronic layout plan

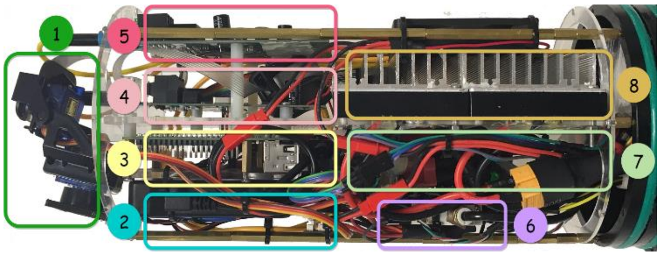

Figure 9. Photo of electronic layout (Side view)

Control system

With the reference to previous experience, we have a major change in the design of the control system. Instead of developing a new control system, we have used an open source controller "Pixhawk" as shown in Figure 10. "Pixhawk" has extensive capabilities, which consist of feedback stability control, depth and heading hold, and autonomous navigation. "Pixhawk" not only supports the depth and heading hold which we have done before, but also supports the Inertial Navigation Filter which can greatly improve the stability of ROV. Comparing to the previous 16Mhz 8-bit Arduino based control system, "Pixhawk" uses 180Mhz 32-bit MCU which will operate faster. It is essential for the control system as it involves complicated calculation in feedback control and digital filter. All pilots agree that the ROV is much easier to control and tasks can be executed easily.

Figure 10. Pixhwak

DC-DC converters

DC-DC converters are used to supply power with different voltage levels to various devices. Last year, the noise from the onshore power supply and the tether affected the electrical system of Upstream causing the ROV to shut-down during mission. In order to tackle this problem, the converters were changed to isolated converters. The isolated converters can isolate the noise from onshore and the tether to provide a stable power supply. Although the efficiency of the new converter is lower, it has a higher power density and wider input voltage. The differences are given in Table 1:

Brand/product	cosel CDS6004812 (Use in this year)	eveps ev240-K4812 (Used in last year)
Type	Isolated Buck Converter	Buck Converter
Input voltage(V)	36-72	40-60
Output voltage(V)	12.5	12
Current(A)	56	20
Isolated	yes	no
Efficient (%)	>88	>90
Weight(g)	200	300
Dimension(mm)	61*12.7*116.8	74*74*32

Table 1. DC-DC converter specifications

Power module

This year, we have employed two power modules to monitor the output voltage and the current of the DC-DC converters. If there is any abnormal voltage or current, the system will alarm the pilot and surfacing automatically. With the power monitoring, the ROV can operated in a safer way. Moreover, it consists of a 5V 3A DC output which can provide the power to Raspberry Pi and Pixhawk.

Optical fiber

For the signal transmission media, we have chosen optical fiber instead of copper wire. There are three main reasons namely to minimize Electromagnetic Interference (EMI), reduce weight and increase flexibility as a tether configuration [2]. In our configuration, we have used two optical fiber converters in Figure 11 for analog video and Local Area Network (LAN) respectively.

Figure 11. LAN to optical fiber converter

The communication between onshore computer and the onboard Raspberry Pi is through LAN in order to have higher reliability and greater bandwidth. However, the traditional Cat 6 LAN cable is too heavy and not flexible by using eight core copper wires. Comparatively, optical fiber converter provides a quicker and easier way to change from copper wire to optical fiber.

Tether

The tether consists of two single mode optical fibers, two conductors and a pneumatic tube attached to it, as shown in Figure 12. To ensure a secure retreat under emergency, the tether was reinforced with Kevlar material and have strain relief at both ends connected directly to ROV and Ground Station. Tether was also cover with yellow PU Foam to achieve neutral buoyancy from a more stabilized propulsion and eye-catching colors for identification.

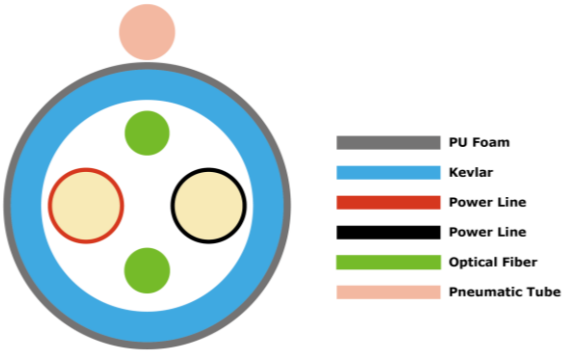

Figure 12. Cross-section of tether

Vision System

Upstream is equipped with a well-designed vision system for navigation purpose. This year, we employ four rotatable cameras and two fixed cameras and it can provide a 360° view around the ROV as shown in Figure 14, and the optical fiber transmits the signal in the system.

The previous generation of Upstream employed IP cameras and web cameras, yet the latency of the digital system (i.e. IP camera system) increased the operational difficulty. Per Hill et al. [1], 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 and the latency has reduced from 250ms to 80ms.

The Upstream iconic rotatable camera was manufactured by mounting a wide-angle analog camera on a servo motor inside an acrylic tube which provides a 270° view underwater. Nearly spherical vision can be provided with four rotatable cameras.

For the fixed camera, it is casted and molded in a 2 x 2 x 2 cm cube-shaped epoxy which is smaller and lighter than commercial waterproof cameras. There may be a problem of reducing the view angle of camera because of light reflection. Fortunately, it can be prevented by making air gap before solidifying the fixed camera with epoxy. However, the aforementioned drawback was negligible after reconsideration because the fixed camera could provide the view which is blocked by other equipment and cannot be captured by the rotatable cameras.

Since image processing is adopted this year, a digital camera is needed. We have employed a USB Camera which can transmit the image through UDP to the onshore computer so as to conduct image processing. We have tested and optimized the system and the latency can reach as low as 100 ms which is still acceptable for the real-time video streaming.

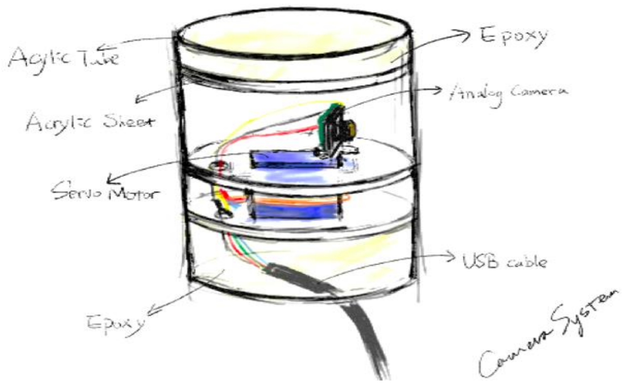

Figure 13. Concept drawing of rotatable camera

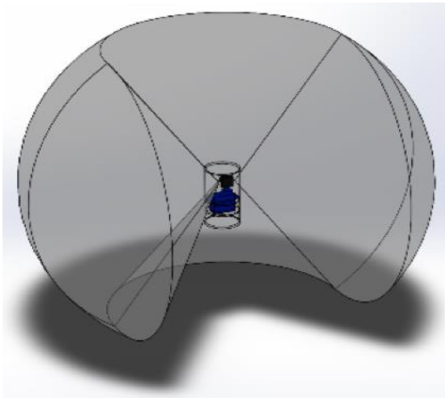

Figure 14. Rotatable camera view angle

Control Panel

Figure 15. Control panel

We reused the control panel, as shown in Figure 15, from last year due to its high flexibility and user-friendly layout. Meanwhile, we have developed a virtual panel in the GUI as a backup solution. The control panel is installed in a case which makes the ROV control system portable. A lightweight and durable case with waterproof and corrosion resistance properties' case is selected to be the container of the control box to well protect the entire control system. Since not only a circuit breaker, but also all the switches are placed and installed in the control panel in an organized way. With a centralized control system, the ROV is easier to operate. Moreover, the control panel has been enlarged in scale which allows more than one operators to control the ROV simultaneously.

D. Software Design

Onshore control system

To connect "Pixhawk", subsystems and other input and output units of Upstream, a software is developed using the Python 3.4. programming language. This program acts as the center of the whole control system to give commands to ROV, receive data from ROV, collect input from the user through the Xbox controller and control panel, and display the status of the ROV

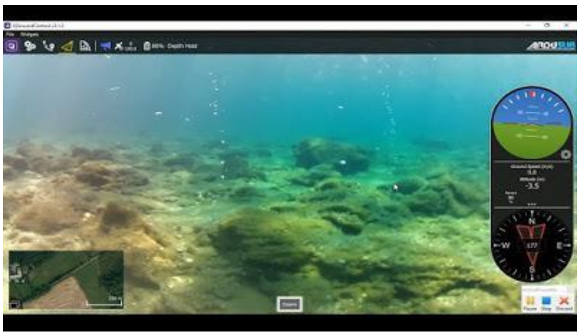

Figure 16. Working state of GUI

on a GUI as shown in Figure 16. The Xbox controller is responsible for sending commands for the movements of Upstream. The directions and output power of thrusters can also be adjusted by using the Xbox controller to carry out different movements of the ROV, like moving forward or backward, shifting left or right, and rotating clockwise or anticlockwise. The control panel provides a simple interface for the pilot to control other subsystems, such as lighting, buoyancy and manipulator.

iControl

Since the "Pixhawk" system only provides the basic control of the ROV, we have developed a new user-friendly and cross-platform GUI based on JavaScript and HTML, named iControl as shown in Figure 17. It provides Web Socket and Serial connection between our control panel and Raspberry Pi. Also, it presents OBS Wi-Fi data, seismograph and computer vision image. Formerly Node-Webkit (NW.js) framework is adopted because it can be implemented directly from DOM and enables an efficient way of writing Windows desktop application with all Web technologies such as HTML5, CSS and JQuery. Compared to last year Python-based GUI, iControl offers a better utilization of asynchronous function which maximizes the stability of network connection. Since iControl is independent of the whole control system, the changes and commands in "Pixhawk" or iControl will not affect each other. Besides, iControl requires less computing power and is able to be implemented on multiple operating systems.

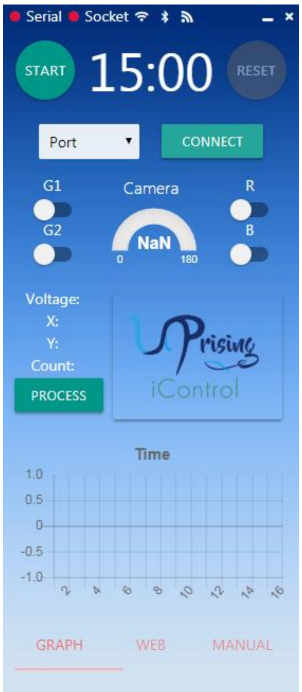

Figure 17. iControl GUI

Apart from providing efficient communication among the control system, iControl provides some special features that assist the co-pilot in completing the missions. Timer reminds the co-pilot to achieve time management during the product demonstration. A virtual panel provides a backup solution if the control panel malfunctions. The navigation bar shows the current connection status and condition. The flowchart of system software and block diagram are given in Figure 18 and 19 respectively.

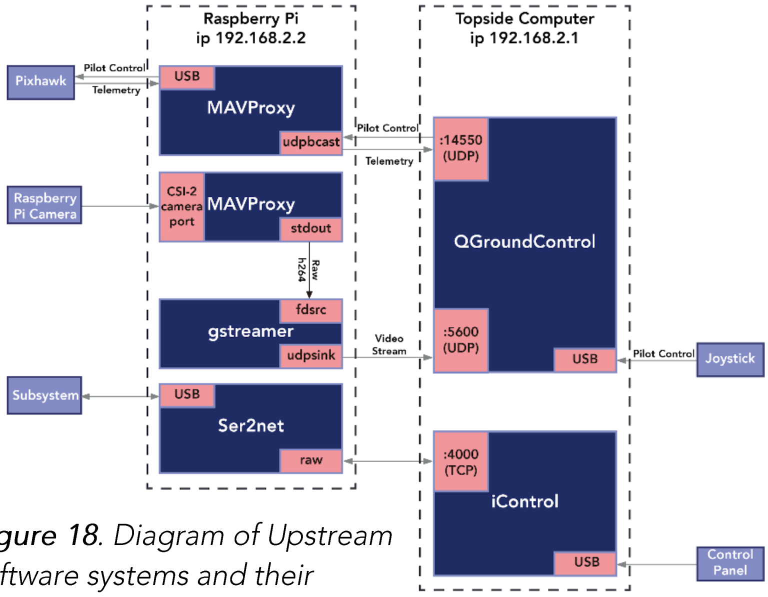

Figure 18. Diagram of Upstream software systems and their interactions

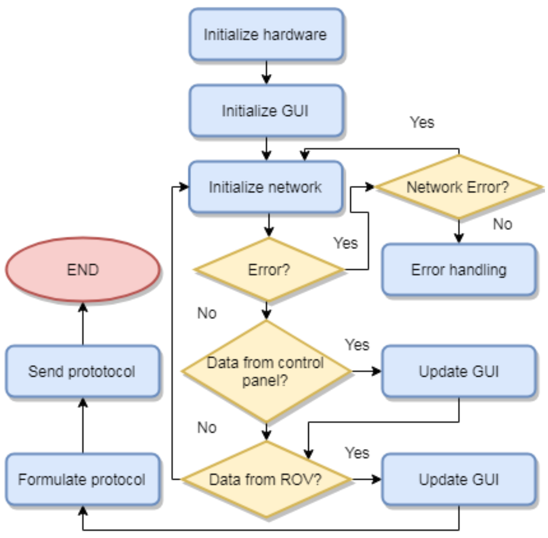

Figure 19. Program running flowchart

E. Mission-Specific Design

I. AIRCRAFT

Computer Vision

The image processing part of the project aims to recognize the characteristics of the aircraft's tail structure. By extracting a specific color using HSV color range filter, one of the specific color can be separated from the raw image and form a mask layer. The mask layer will only contain one specific color of the segment which could outline the shape of the aircraft's tail structure. After that, the mask will perform Morphological Transformation, Gaussian Blur and Thresholding Operations by using the OpenCV library based on Python. This could optimize the polygon shown on the mask. When the software finds the contour of the debris, it will approximate the shape of the debris with another curve with less vertices. Figure 20 shows a result of our underwater image processing test. The algorithm draws the contour of the blue triangle and label "C" in blue is shown at the upper-left corner which is requested by the task. Detail description of the image processing algorithm is provided in a separate submission.

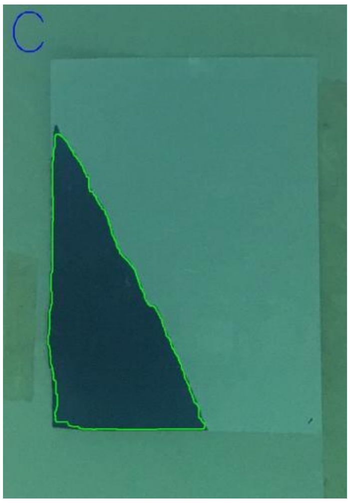

Figure 20. Processed underwater image of the plane debris

Lift Bag System

Two lift bags are used in Upstream. To complete the tasks, one lift bag is designed to attach and release the load automatically as shown as Figure 21, which is used for lifting the debris. The other lift bag can only be attached automatically, it can only be released manually on ground. This one is designed to lift the engine.

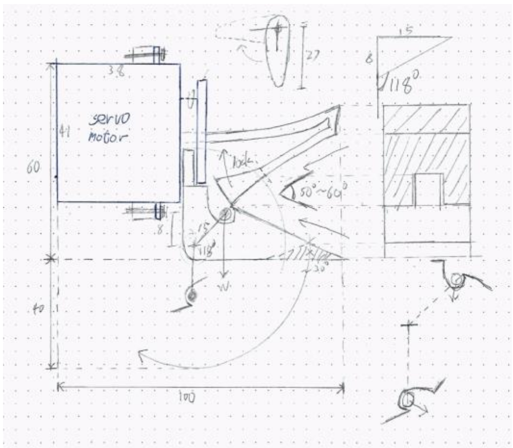

Figure 21. Concept drawing of lift bag release system

For the automatic attach/release lift bag, waterproof servo motor and a Bluetooth module are used. The lift bag is aimed to lift the debris, it includes an electrical release hook (using a servo motor), Arduino, battery and lift bag. The Arduino is connect to a HC-05 Bluetooth module, the open and close signal is transmitted by the Bluetooth, then the Arduino will adjusted the angle of the servo motor to open or close the hook. The lift bag is connected with a Schrader Valve with a Schrader Switch. Before doing the task, the lift bag is folded. After attaching the load, pressured air is pumped from ground air supply to the lift bag through an air hose. When the lift bag begins to rise, it will trigger the Schrader Switch, then the Schrader valve will separate from the ROV. By using a rotational interlock, the load can be released by transmitting a unique signal via the Bluetooth module.

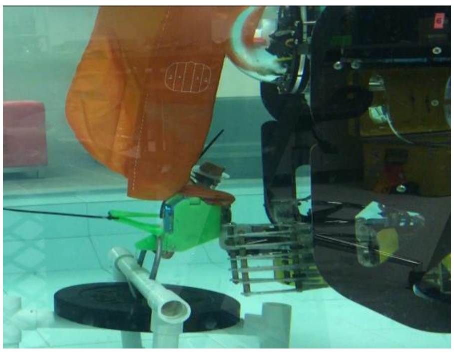

Figure 22. Upstream attaching lift bag

The batteries and the mini-pro Arduino is housed inside the container made by a modified syringe, and the Bluetooth and servo motor is fixed and waterproofed with epoxy outside the syringe. The syringe has good performance of waterproof and it can bear the depth within the competition requirement. Meanwhile, because the plug of the syringe can be moved easily if the pressure inside increases. When the pressure is too high then the plug will go off.

II. EARTHQUAKES

Inductive Coupling Connector

To power up the inductive coupling for wireless power transmission, our device was equipped with a 9V battery, a 5V regulator and the transmitter. The whole circuit is located inside a modified watertight cup. The 9V battery is affixed to the inner wall of the container by using Velcro. The 5V regulator will step down the voltage to 5V, to power-up the transmitter coil. If the inner-pressure of the watertight cup is greater than the surrounding water pressure, the lid will go off.

Figure 23. Inductive Coupling Connector

OBS Leveling Turner

Figure 24. OBS leveling Turner

The OBS Leveling Turner, as shown in Figure 24, is designed to turn the knob when leveling the OBS. The turner is made by 3D printed PLA and driven by a stepper motor. Since an accurate and customized shape is needed, 3D printing is the most effective way to achieve this goal. As the knob may start at any angle, for a quicker and simpler operation, one objective of the design is to allow to grip the knob at any angle. Therefore, we designed a cylinder turner with six slots. The cylinder is hollow for inserting the knob and the diameter of inner wall is just fit in a knob to align the rotation axis of turner and knob. There are six small triangular teeth inside the cylinder and force the knob to rotate with the turner. Six is the maximum number of teeth that can insert and it has already provided a slot for every 60 degrees. The opening of the turner is inclined inward. As a result, the knob can easily slide into the turner. Moreover, the tip of the teeth is inclined to slightly adjusting the angle of the knob to fit in the closest slot.

Wi-Fi Module

Extracting the data from the information received by the OBS requires an ESP8266 Wi-Fi transceiver module, to level the OBS and collect the seismograph data. ESP8266 is a small and low-cost Wi-Fi microchip for exchanging data over a very limited distance under water. ESP8266 can set up its SSID, operation mode, baud rate and other connection configuration using AT-command. The module will connect to the pre-programmed Arduino which is used to control the data transmission between the Wi-Fi transceiver module and our main controller. Naturally, we need the ESP8266WiFi and ESP8266HTTPClient library that provide methods to send HTTP GET requests. To secure that the Wi-Fi transceiver module works normally under water, the entire device is protected by epoxy as shown in Figure 25. Testing is required to ensure the ESP8266 can auto-pair with another module under water.

Figure 25. Wi-Fi module shielded with epoxy

III. ENERGY

Manipulator: Electric Gripper

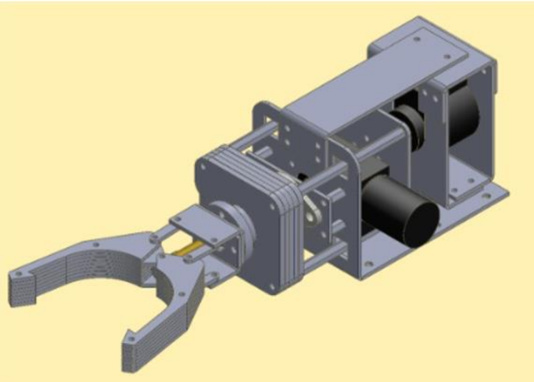

Figure 26. *Electric gripper*

The electric gripper, as shown in Figure26, is designed to execute various tasks, such as inserting the power connector and installing the turbine base. The gripper used in last year was reused because of its two degrees of freedom and general usage which can reduce the total number of required tools and weight. The design is able to manipulate a variety of objects and PVC pipes in multiple orientations. The gripper is driven by a waterproofed DC motor and a telescopic stepper motor, together with a simple rod and nut system. A DC motor is used for rotating the gripper and a stepper motor is used for opening and closing the gripper. The mechanical components of the gripper are constructed by an aluminum plate. The aluminum plate is sheeted by metal punching machine. Besides, the clamp part has been modified to V-clamp because it has a specific and unique curvature that hold the objects tighter and firmer by fitting the dimensions of different objects. Modifications were made by SolidWorks and the prototypes were extensively tested. Eventually, the one with the best performance was selected. Moreover, the rubber is attached to the V-clamp in order to increase their coefficient of friction and grip.

Distance Measurement Tool

The purpose of the Distance Measurement Device, as shown in Figure 27, is to provide a genuine and accurate measure of distance between objects. With the aid of rotatable cameras, we can obtain the readings on the measuring tape. To measure the distance, we need to find a fixed reference point on that object and then extend the tape.

Figure 27. *Distance measurement*

Acoustic Doppler Velocimeter (ADV)

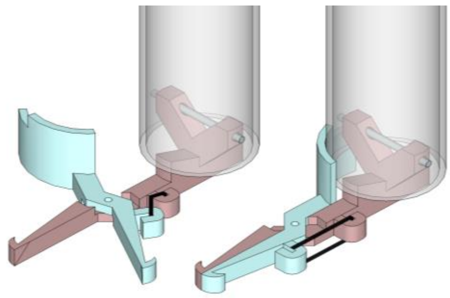

Figure 28. *ADV attaching tool*

In order to attach the ADV rapidly, Uprising designed and built a scissors-like tool rather than using any S-shape hook in the market. The ADV is made by an acrylic tube with foam and 3D printed attaching tool. The ADV is first gripped by the electric gripper which limits the attaching tool to "closed" position. Once it is in position, it will be released from the electric gripper, and then the rubber band will force it open immediately and restricted by the U-bolt, as shown in Figure 28. Compared with a S-shape hook, our attaching tool has the benefit of easy U-bolt access and is less affected by water current.

Multifunctional Hook

The multifunctional hook can be attached to the U-bolt also the horizontal pipes such as tidal turbine and I-AMP. The hooks have no locking system, therefore the structure becomes simple and the attached props will automatically disconnect from the hooks when it touches pool bottom. Before the dropped props stand stable, the hook can prevent it from falling, and then totally release once it is stable.

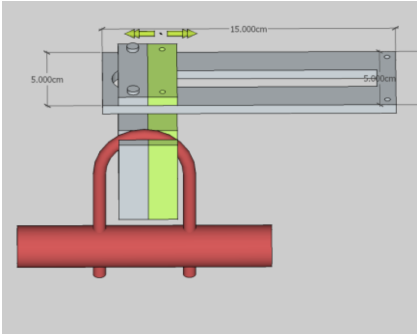

Figure 29. Multifunctional Hook

Swan Gripper (Lightweight Props Handling Tool)

Figure 30. Swan Gripper

To minimize the number of journeys needed for ROV to travel to take and install all the props used in tasks, handling tools are designed to help Upstream to take more props at a single journey. However, the weights of the props are varied by a large extend. To address the requirement of carrying and installing light-weighted props, Swan Gripper, as shown in Figure 30, is engineered to enable secure attachment of light-weighted props to attached and detach them easily with a simple mechanism. This device works perfectly for cylinder-shaped and light objects. In addition, the device is designed to be one-sided opening and suitable for performing precise attachment. The sharp and shovel-shaped region is designed to handle some difficult situations which are hard to handle for two-sided opening gripper.

3. Safety

A. Company Safety Philosophy

Safety is the first priority of Uprising Inc. and is always taken very seriously when manufacturing Upstream. Numerous rigid safety protocols are strictly implemented during the design, building, handling and testing of the ROV.

B. Lab Safety Protocols

For the sake of employees' safety, our company adopts stringent safety measures required by the Industrial Center of The Hong Kong Polytechnic University and strictly follows the safety checklist provided by MATE. Additional safety measures will be taken when encountering new challenges. We train every employee on safety practices in terms of safety awareness, basic safety requirements, hazardous materials, incision and fixture tools.

Figure 31. Company's staff work with safety protection

When handling soldering work or energized circuits, it is necessary to have at least two persons present in case of any danger. Appropriate safety equipment, such as safety goggles, ear protection and safety shoes, are required when dealing with power tools. Masks and gloves are always worn when handling hazardous chemicals, like epoxy. Moreover, electrical outlet or switch should not be operated if the protective cover is cracked or left ajar.

C. Safety Features of Upstream

Upstream contains plenty of safety features to keep our personnel, Upstream and the working environment safe and healthy. For the electrical and electronic divisions, extra safety measures are required and they are mentioned as follows. Laser cut acrylic motor shrouds are used to cover the thrusters and reach the IP2X protection level as shown in Figure 32. Fuse is installed in live wire and no Tee-joint is allowed ahead of the fuse. Moreover, various waterproofing techniques are applied to ensure that no water leakage occurs.

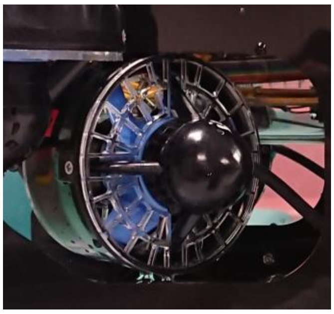

Figure 32. Laser cut acrylic motor shroud

D. Safety Checklist

Operational safety protocols are dictated by Uprising's safety checklist in terms of pre-power, on-power, ROV retrieval and leak detection protocol. They are closely followed before and after deployment of Upstream. Some are presented as follows.

Pre-power ❏ Clear the area of any obstructions ❏ Verify power supply is "OFF" ❏ Check for any loose components or any physical signs of damage on Upstream. ❏ Ensure that all waterproof connections have O-rings and are tightly sealed. ❏ Connect tether to ROV ❏ Set compressor output to 275 kPa	On-power ❏ Check that the voltage on Upstream tether is 48V, and that the outputs of 48-12V and 12-5V regulator are 12V and 5V respectively. ❏ Test all thrusters, pneumatic actuators, and cameras ❏ Control side calls "Launch" ❏ Handle ROV into water ❏ ROV is neutrally buoyant ❏ Shore side calls "Go"
ROV retrieval: ❏ Control side calls "Retrieve" ❏ Check if the thrusters stop running before taking Upstream out from water. ❏ Deployment team yells, "ROV retrieved" ❏ Launch ROV ❏ Bring items to control side	Leak detection protocol: ❏ Check for any air leaks on Upstream by switching the air compressor on. End of mission: ❏ Control side calls "Bring up" ❏ Bring up ROV ❏ Power down ROV, control box and air compressor

4. Project Management

A. Company Structure and Work Allocations

This project has broken down into three major parts – project management, software and hardware. Workload has also been allocated to different components of our organisation structure. Please refer to Figure 33 for the company structure. This work breakdown structure was extensively used to create mini tasks, which form parts of a larger sub-project. Doing so makes allocating jobs a lot more manageable and traceable.

Uprising Inc. consists of three departments and they are: Mechanical Department, Electrical Department, and Software Department. The Mechanical and Electrical Departments have to deal with the design and technical issues of the ROV's hardware components, such as electronics soldering onto circuit boards, waterproofing the key electronics chambers, designing the circuits, and choosing the components. The Software department has to program the Arduino microcontroller, the Raspberry Pi and design algorithm to calculate the dimensions of object through images obtained with the cameras.

In terms of project management, "Product and Safety Manager" cooperates with the three department heads and the "Chief Technical Officer". He also acts as a linkage between three departments and the safety of the project. "Chief Technical Officer" is responsible for the overall design and operations of ROV. "Chief Financial Officer" is responsible for the financial status, planning and management of the company, such as making budget plan. "Chief Operating Officer" is responsible for working with operational officers and deal with the marketing and operating issues in the organization, for example, integrating and elaborating each part of the project proposal and poster. The "Chief Executive Officer" of the Uprising Inc. has the role of overseeing the operation of the company and the progress of the project, like designing the Gantt chart to monitor and make sure the project is keeping track with the ideal schedule.

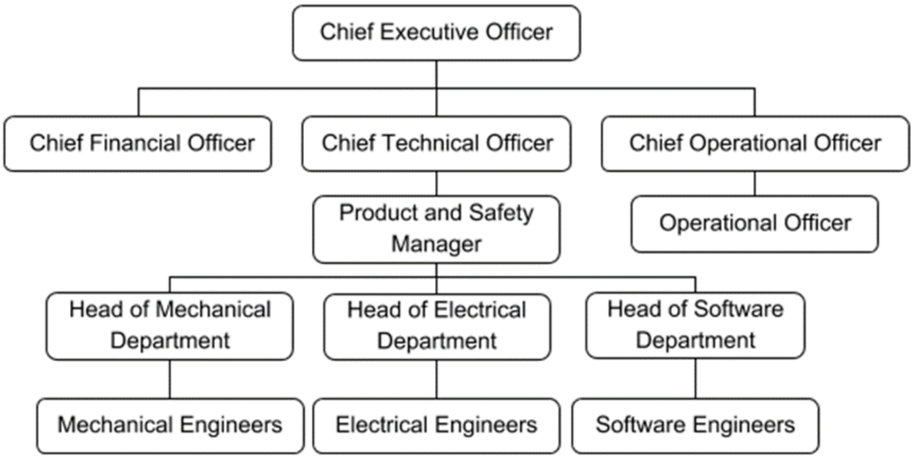

Figure 33. Company Structure of Uprising Inc.

B. Schedule

The schedule is mainly divided into four major part: training, designing, building, and testing. During the training procedure, new employees will learn all the basic knowledge of building the ROV and the detail of the completion. After training, the company moves into development stage. Divide the team into three main part, electrical and electronic, software and mechanical system, which designing at the same time. In the building phase, the company manufactures the frame, software and tools. In the testing stage, it consists of pilot practice and regional competition. If any problem is discovered during this stage, parts will then be redesigned and manufacture.

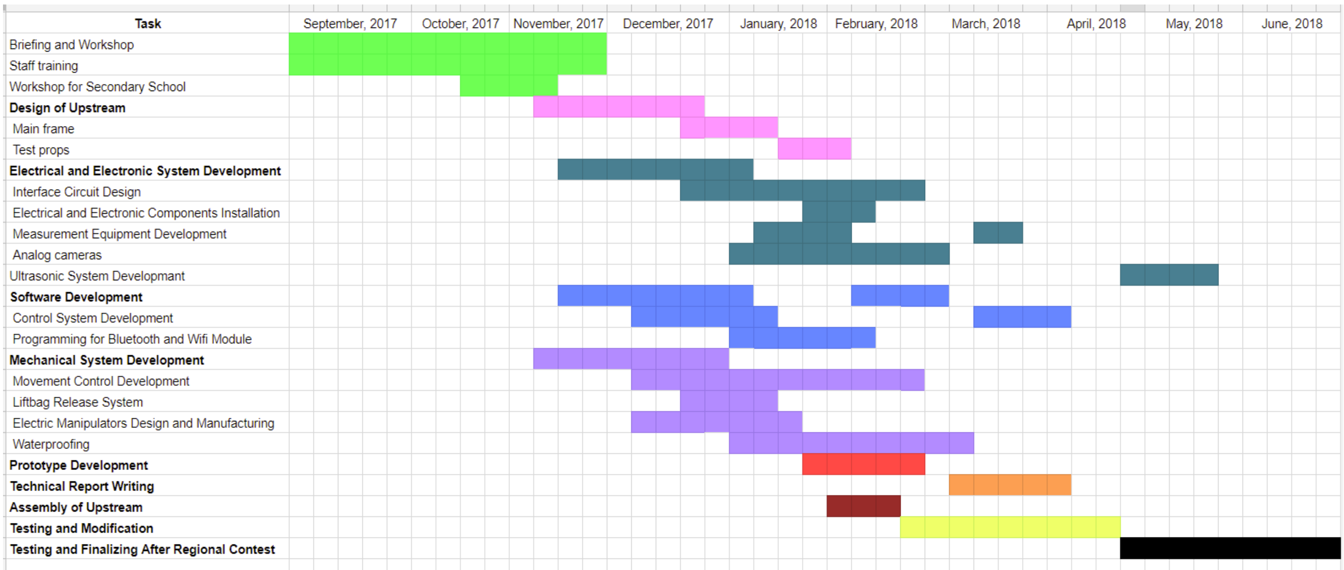

Figure 34. Gantt chart of schedule

C. Budget and Project Costing

In this project, the mechanical part of the ROV possessed a huge amount of resources, especially the BlueRobotic T200 and the frame. This is because redesign and re-generate process of the frame is needed. Fortunately, having the experiences of participating in previous year's MATE competition, there are a number of ROV components could be reuse which help to save money and time. For example, the camera system and control panel system.

I. Budget

Travel Expenses (RMB)		Machine Development (RMB)		Sponsorships (RMB)	
Airfare (13 member)	$35,000.00	Mechanical Components	$4,000.00	PolyU EE Department	$5,000.00
Hotel (5 night, 7 room)	$41,600.00	Electrical and Electronic Components	$13,000.00	Hong Kong Airlines (Air ticket)	$83,500.00
		Control Box	$2,000.00		
Travel Sub-total	$157,600.00 (USD$20,083)	Operation Sub-total	$19,000.00 (USD$2,978)	BUDGET NET TOTAL	$88,100.00 (USD$13,810)

II. Project Costing

Type	Category	Item Name	Cost	Budgeted Value
Mechanical Components				
Purchase	Frame	HDPE Frame	$ 680.00	$ 680.00
Purchase	Frame	Chamber	$ 629.00	$ 629.00

Re-use	Electronic	Tether	$ 1,690.00	$ -
Purchase	Task	Lift Bags	$ 600.00	$ 600.00
Purchase	Task	Off-load Hooks	$ 40.00	$ 40.00
Re-use	Task	Air Tube	$ 100.00	$ -
Purchase	Task	Schrader valve and quick releases	$ 51.00	$ 51.00
Re-use	Tools	Optical Fiber Toolkit	$ 200.00	$ -
		Mechanical Components Sub-Total	$ 3,990.00	$ 2,000.00
Electrical and Electronic Components				
Re-use	Thruster	BlueRobotic T200(8pcs)	$ 9,600.00	$ -
Purchase	Electronic	20A ESC(8pcs)	$ 300.00	$ 300.00
Purchase	Electronic	PixHawk	$ 300.00	$ 300.00
Purchase	Electronic	Pixhawk power module(2pcs)	$ 90.00	$ 90.00
Re-use	Electronic	Raspberry Pi	$ 230.00	$ -
Purchase	Electronic	USB Cam	$ 54.00	$ 54.00
Re-use	Electronic	Arduino Pro Mini	$ 20.00	$ -
Purchase	Electronic	DC-DC converters	$ 276.60	$ 276.60
Re-use	Electronic	Fiber Optic Media Converters(2sets)	$ 470.00	$ -
Re-use	Electronic	Motor drives	$ 40.00	$ -
Re-use	Electronic	Motors	$ 120.00	$ -
Purchase	Electronic	HS-646WP servos	$ 440.00	$ 440.00
Re-use	Electronic	Bluetooth Module	$ 40.00	$ -
Purchase	Task	ESP8266 WiFi Module	$ 20.00	$ 20.00
Re-use	Electronic	Waterproof Connectors	$ 275.00	$ -
Purchase	Electronic	Silicone Wire	$ 10.40	$ 10.40
Re-use	Camera system	Rotatable Cameras	$ 490.00	$ -
		Electrical and Electronic Components Sub-Total	$ 12,776.00	$ 1,491.00
Control Box				
Re-use	Camera system	8 Channel DVR	$ 145.00	$ -
Re-use	Control Box	19' LCD Monitor	$ 800.00	$ -
Re-use	Control Box	Hardcase	$ 800.00	$ -
Re-use	Control Box	Control Panel	$ 105.00	$ -
Re-use	Control Box	Xbox360 Controller	$ 300.00	$ -
		Control Box Sub-Total	$ 2,150.00	$-

Travel Expenses				
Travel Expenses	Flight	Hong Kong To Vancouver(tax)	$ 6,500.00	$ 6,500.00
Travel Expenses	Flight	Vancouver to Seattle	$ 21,157.12	$ 22,000.00
Travel Expenses	Hotel	5 night, 7 room	$ 35,594.72	$ 36000.00
		Travel Expenses Sub-Total		
		Total Cost in RMB	$ 82,167.84	$ 67,991.00
		Total Cost in USD (1 USD=6.8918RMB)	$ 11,925.67	$ 9,868.07

5. Retrospect and Prospect

A. Testing

Uprising implemented air tightness testing, as shown in Figure 35, to measure the extent of which air is lost through leaks in the electronic chamber. By using a hand operated pump to reduce the air pressure to 50 kPa inside the chamber, if the reading of the pump does not change after 10 minutes, then electronic chamber is proved to be air tight and waterproof. Otherwise, there is a risk of water damage to electronic components.

Figure 35. Air tightness testing in progress

To ensure Upstream has the stability and ability to accomplish all the tasks request by MATE. Upstream has been tested in pools which show Upstream can fulfill the contract requirements in providing a ROV for working in open water to support Pacific Northwest area of Washington State. A crew of members should prepare for each test in terms of packing and arrangement of rundown, not to waste a minute without doing enough testing as problems could only be solved once discovered. With limited time of full system test, objectives must be clarified to avoid aimless move. As important as spare parts, plan B is a plan A when Murphy's Law takes place, the smallest test could be the only step we could take better than halt progress.

B. Troubleshooting

I. Voltage spike by the back EMF

During the first water test, we found that the overvoltage protection of DC-DC converter was triggered after any movement. We conducted some debugging and troubleshooting immediately. Then we discovered that it was triggered by the voltage spike generated by the back EMF when the thruster stops. After conducting some research, there are some solutions like adding a diode in series in the converter output. However, we chose to use the transient voltage suppression (TVS) diode [3] to absorb the transient energy generated by back EMF. It can prevent the triggered overvoltage protection and protect other electronics systems in the same busbar. Moreover, it absorbs the transient energy and converts to heat. Comparing to the series diode, it can only prevent the overvoltage protection been triggered, but not absorb the energy and protect other electronic systems.

II. Latency of Digital video transmission

We used to have a digital camera system in the previous ROV. We have changed to analog camera system due to the high latency problem. Since the image processing is required this year, we must employ some digital cameras to finish this mission. After having some tests, we found that in specific configurations, the latency can be less than 100ms. However, this configuration can only apply to single digital camera system. Therefore, we have only employed one digital camera in Upstream.

C. Challenges

I. Technical

This year, a lot of improvements have been applied to the ROV, especially on the choice of material for the frame, integration of different new technologies and redesigning the ROV to perform the required tasks in an efficient way. Through some trials and learning from failures, we have acquired and enhanced many skills like image processing and 3D printing. For instance, the ROV is required to complete task 2 with an inductive coupling connector. It is the first time for the team to use wireless power transmission. With adventurous spirit and eager to learn new skill, we applied it to Upstream successfully. This experience did encourage the team to be creative on thinking various solutions to complete other tasks.

We also found that the simpler the engineering design, the better the performance. We redesigned the ROV by using different materials like HDPE and Carbon Fiber. It reduces the weight to allow better and more accurate movement control. By various tests and comparisons, Uprising Inc. gets to know more about the advantages and disadvantages on materials and shape design. Finally, we decided to use a modified syringe for the battery container. It has good performance on both waterproof and pressure release without pressure sensor and motor.

II. Interpersonal

During the competition, we faced some non-technical challenges which hindered the schedule. One of the obstacles was lack of benefactors sponsoring fund and materials, like equipment used for testing and commissioning. For constructing the robot, Uprising Inc. required different costly equipment for modification, set up and testing, so as to enhance the ROV. Under these circumstances with lacking resources, the team tried to ask certain companies for the useful equipment and resources, to minimize the budget.

Apart from the budget, the dependence on the 3D printer was high, only one printer was not enough to satisfy the demand of it. Paying manufacturers to print the components of the design was a burdened as the service charges were expensive. However, this expense was diminished due to the sponsorship given by the Department of Electrical Engineering, PolyU for a new 3D printer that helps Uprising Inc. to save funding.

The tight schedule is another challenge, as plenty of work needed to be completed with limited time. The local competition date was held in April which was overlapped with the examination period, and our employees were, at the same time, facing final examinations and preparing the final stage of competition. In the face of huge workload, Uprising Inc. had a well-planned division of work in accordance with the expertise of group mates. The crews all put on consistently distinguished performance and displayed conscientiousness and diligence in performing tasks.

Also, one of the difficulties in the competition was that more than half of the teammates are inexperienced in ROV. It is the first time for these members to participate in the activity. To overcome this problem, the experienced members arranged extra workshops to train the newcomers and teach the basic techniques to them.

D. Lesson learnt

I. Technical

This year, a lot of improvements have been applied to the ROV, especially on the choice of material for the frame, integration of different new technologies and redesigning the ROV to perform the required tasks in an efficient way. Through some trials and learning from failures, we have acquired and enhanced many skills like image processing and 3D printing. For instance, the ROV is required to complete task 2 with an inductive coupling connector. It is the first time for the team to use wireless power transmission. With adventurous spirit and eager to learn new skill, we applied it to Upstream successfully. This experience did encourage the team to be creative on thinking various solutions to complete other tasks.

II. Interpersonal

Under high demand and heavy workload, the crews have gained experience in self-management and self-initiative with our determination. In response to the crowded and compressed schedule, Uprising Inc. has created division of work with a to-do list showing the tasks that each employee should be responsible for. Employees who finished their own work efficiently could enjoy the rest of their time or contribute to the accomplishment of others' work. Uprising Inc. has run in an effective and efficient manner in a way to secure the development process of Upstream with full participation.

Teamwork and team collaboration have long been the significant factors in all group-based contests. Before joining Uprising Inc., some employees were not acquainted with each other because all of us come from different disciplines and different study years. To ensure the aforesaid factors, many bonding activities, like hiking and lunch gathering were regularly held to allow employees to get in touch with each other, and to tackle language barrier and different cultures. We have shared experience and expertise to achieve the same goal – developing the best "Upstream" ever. Communication is always needed when different parts of work were ready for integration, hence we established friendship.

E. Reflection

I. Senior

"The joy that MATE competition brought to me has driven me to grape this wonderful learning experience again this year. Even though this year is the 2nd year for me of joining the MATE competition, I have some breakthroughs this year. Using the experiences of being last year competition project manager, I have re-developed and modified the project schedule and the work distribution plan based on our teammates' capabilities and talents. It was really an enjoyable time in spending all the sleepless nights filled with both stress and laugher. Working with PolyU ROV Team has definitely added a different flavor to my university life and given me an unforgettable experience worth cherishing."

--- Sum, Chief Executive Officer

"Joining the MATE competition last year left me with many new ideas and unfulfilled goals that made me want to participate once again. This year I have set myself new goals which would grow on a team level for the upcoming MATE competition. Being a senior member, I have been challenged to guide a group of teammates by developing a timeline and delegating individual work to them."

--- Paul Wan, Chief Technical Officer

II. Junior

"As a freshman, I am excited in participating MATE competition 2018. With the supervision and recommendation from my senior teammates, I have learnt a lot of technical knowledge and techniques in managing project. The most important thing that I gained in this competition is not technical, but the way of solving a problem. It is fun to join this ROV team, especially when we encountered difficulties. The high spirit in this team lightened up my school life, especially when we stayed together at night building a ROV. With the supports from my teammates, I never get frightened when facing challenges. I am happy to stay active in this team."

--- Henry Kwok, Head of Mechanical Department

F. Further Development

I. Manipulator

The gripper could be increased one more degree of freedom while the shape of the gripper could be redesigned. The gripper can be operated with open, close and rotation now, and could be improved by adding vertical dimension to move in upwards and downwards, then would be able to do more tasks. Therefore, an improved gripper could be multi-functional to execute many tasks.

II. Software Version Control

This year, Uprising software department gains a great success in developing iControl. However, the department hopes to have an efficient method to exchange programming source code. The department is currently using Google Drive to upload and download source files. Uprising software engineers would like to benefit from application development management platform, such as GitHub, which provides excellent documentation and tracks changes across versions.

G. Community Outreach

Uprising Inc. always tries to achieve public needs for our society. STEM education, the mainstream education strategy in recent years in Hong Kong, emphasizes in the application of interdisciplinary knowledge, problem-solving and innovative skills. To keep abreast with this trend, we have planned to set up some STEM learning activities for the society.

This year Uprising Inc. cooperated with HKSKH Bishop Secondary School and organized a series of ROV workshops for their students. Participants are expected to understand the working principles and technical skills in building ROV. With the aim in equipping them with essential STEM knowledge and competencies, we had taught them the programming language, electrical and mechanical concepts during the workshops. Participants also had opportunities to build up their own mini-ROVs. After the intensive training, they could design and build their own robots, which helps them to teach their classmates in their own inner-school ROV workshops.

Besides cultivating effective STEM learners through teaching secondary students to build a ROV, we had also promoted STEM teaching in a community exhibition event, HKSciFest. We taught young children about some scientific theories through making simple electromagnetic device.

We had expanded our coverage to university students as well, to raise their awareness in the importance of applying what they have learnt into creating innovative products. We had organized some introductory workshops that provided opportunities for university students to learn about some of the latest technologies.

This year we have a breakthrough in organizing various kinds of activities which cater the interest of different age groups, to widen the diversity of STEM learners.

Figure 36. ROV workshop for HKSKH Bishop Hall Secondary School

H. Reference

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4. "T200 Thruster." Blue Robotics. http://docs.bluerobotics.com/thrusters/t200/.

I. Acknowledgements

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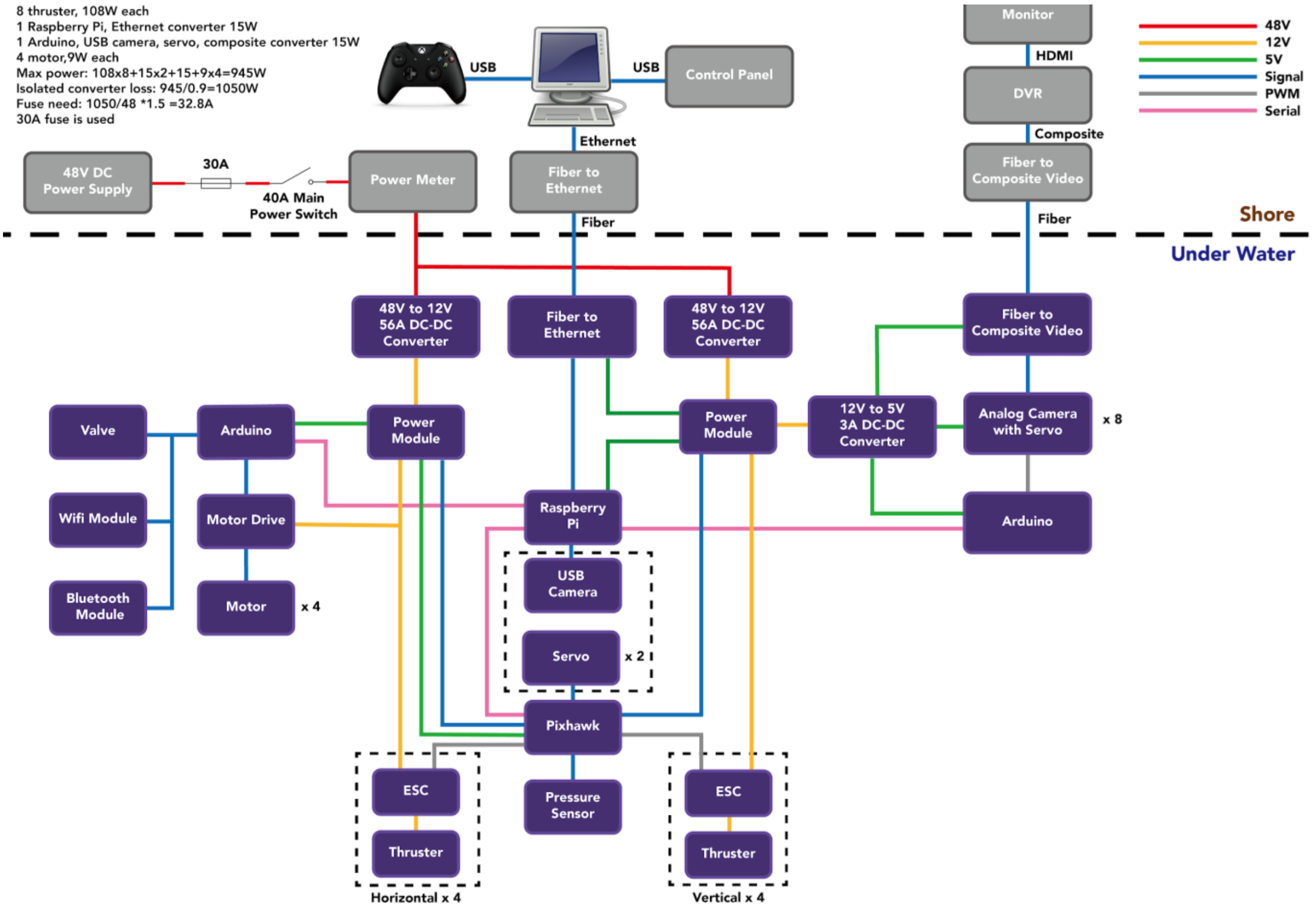
Faculty of Engineering, PolyU – for providing sponsorship;
Department of Electrical Engineering, PolyU – for providing sponsorship and labs to use;
Industrial Centre, PolyU – for providing technical supports and suggestions;
MATE Center – for organizing the international competition, providing a platform 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, and providing advance ROV training workshop;
The Hong Kong Institution of Engineers – The Hong Kong Polytechnic University Student Chapter – for providing supports in helping us to organize community outreach activities;
Hong Kong Airlines – for providing air ticket in supporting us to go to the contest venue

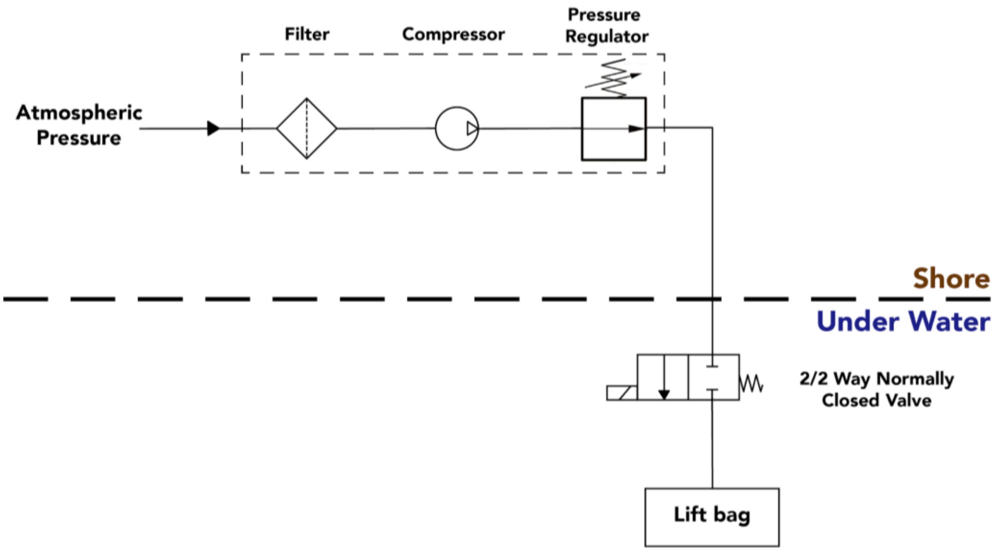
6. Appendix

Appendix A System Interconnection Diagram (SID)

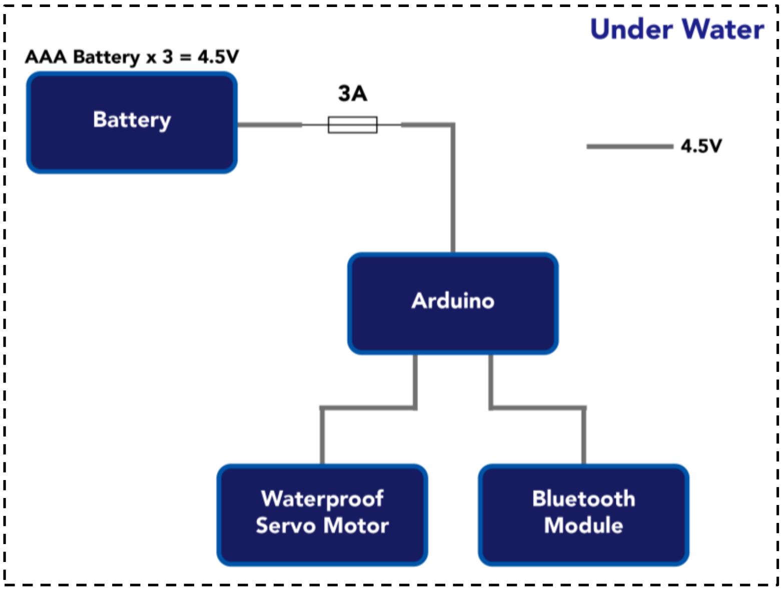
I. Electrical



II. Fluid



III. Lift bag



IV. Inductive Coupling Connector