MATE ROV Competition 2018

# Riverstone Blue Whale II
# Technical Report

## Company Information:

**Name:** Riverstone

**School:** Nanjing Institute of Technology

**Home:** Nanjing, Jiangsu Province, China

## Company Head Coach:

| | |
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| Yu Hanqi | Professor |
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| Yang Xue | Lecturer |
| Xia Ximing | Lecturer |
| Sun Bin | Lecturer |
| Hua Weizhong | Lecturer |

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| | | |
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| Chen Guijiang | CEO | Year 3 |
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| Zhou Shi-ting | CFO | Year 4 |
| Zhang Jianpeng | Electronics Leader | Year 3 |
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| Yang Chengbin | Software Leader | Year 2 |
| Jiang Yuwei | Public Relations Leader | Year 3 |
| Zhai Shuaishuai | Pilot | Year 2 |
| Chen Zhe | Pilot | Year 1 |
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| Xia Jingyan | Safety Manager | Year 2 |
| Wang Xu | Design Engineer | Year 4 |
| Shao Minghai | Electrical Engineer | Year 3 |
| Li Xiangyu | Electrical Engineer | Year 2 |
| Lu Changwen | Electrical Engineer | Year 2 |
| Zhang Jun | Mechanical Engineer | Year 3 |
| Zhang Hongli | Mechanical Engineer | Year 2 |
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| Zhuang Qianhui | Software Developer | Year 2 |
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# I. Abstract

According to the proposal from APL at the University of Washington of designing an ROV to meet the requirements of operating in salt and fresh water in the Pacific Northwest, *Riverstone* set about manufacturing a highly-efficient ROV to finish the tasks including locating the wreckage of an aircraft and recovering its engine, installing or repairing a seismometer, and installing a tidal turbine and relative instruments to monitor the underwater environment.

*Riverstone* consists of 36 students and 6 instructors. The team is divided into two departments: The Technical Department and the Marketing Department. The Technical Department is composed of software, electronic, mechanical divisions and other technical groups. The Marketing Department is responsible for product and graphic design. All departments are closely integrated to design a stable, efficient and safe ROV.

After brainstorming for several days, we created a preliminary scheme. The project has been polished up with trials and experiments. In manufacturing buoyancy and frame, we used advanced technologies like machining, 3D printing and laser-cutting. Blue Whale II changed the electronic housing into distributed layout- the energy system, communication system and control system are installed into electronic boxes, which optimized the distribution to spare room for mission components. Apart from the control system of ROV, we also designed a ground station software for manipulating and simulating. It can help train the pilot and advertise for the company because of its excellent man-machine interaction function.

We believe that Blue Whale II is the optimal solution to meet the demand.

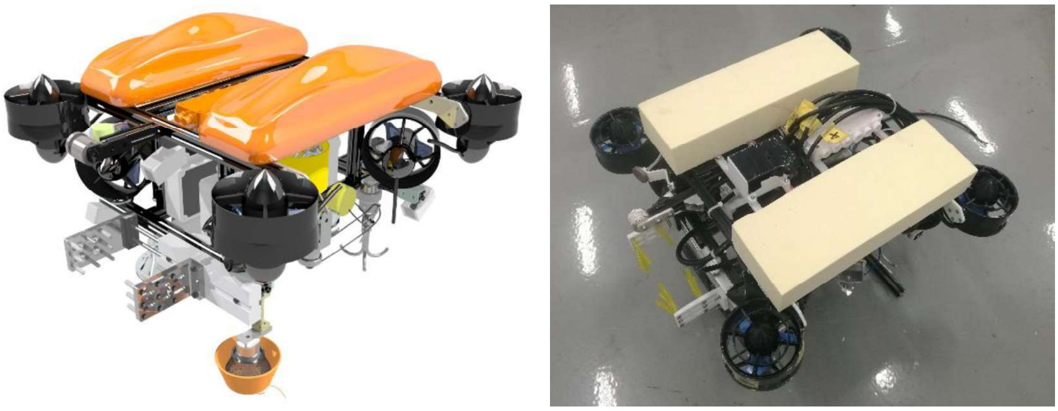

***Figure 1*** *Blue Whale II (Conceptual Graph) & Blue Whale II*

***Figure 2*** *Single: Wu Feng; Bottom Row(lift to right): Lu Changwen, Chen Liming, Li Xiangyu, Zhang Jianpeng, Yang Chengbin, Chen Zhe, XiaJingyan, Jiang Yuwei, He Peiyuan, Hu Yuxiang, Mao Hanxiao, Zhou Shi-ting, Lei Jinwen, Han Lei, Yang Xue, Sun Bin; MiddleRow(lift to right): Wu Heng, Zhai Shuaishuai, Zhang Hongli, Guo Runzhou, Zhu Yong, Shao Minghai, Ma Peili, Li Suhao, Chen Guijiang, Ji Xiaofeng, Chen Wei, Xia Ximing, Zhang Jun; Top Row: Zhang Jun, Liu Jing, Yu Senze, He Chenyu, Zhuang Qianhui, Yan Feng, Wang Xu, Kang Jianwei.*

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# II. Design Rationale

## A. Design Evolution

The design of Blue Whale II began with the consideration of its physical construction. The attached devices were optimized without affecting Blue Whale I's control system. The cross slider of the first generation was replaced for its cumbersome design, inflexibility and unsafety. Although Blue Whale II continued to adopt the pressure-resistant electronic housing, the new manipulator was opted for a balanced layout to allow for a decrease of the electronic housing capacity and an increase of the devices within limited space. Blue Whale II cancels the design of electronic housing for the installation of more mission components inside the frame rather than fix them outside. Thus, Blue Whale II is more concise and multifunctional.

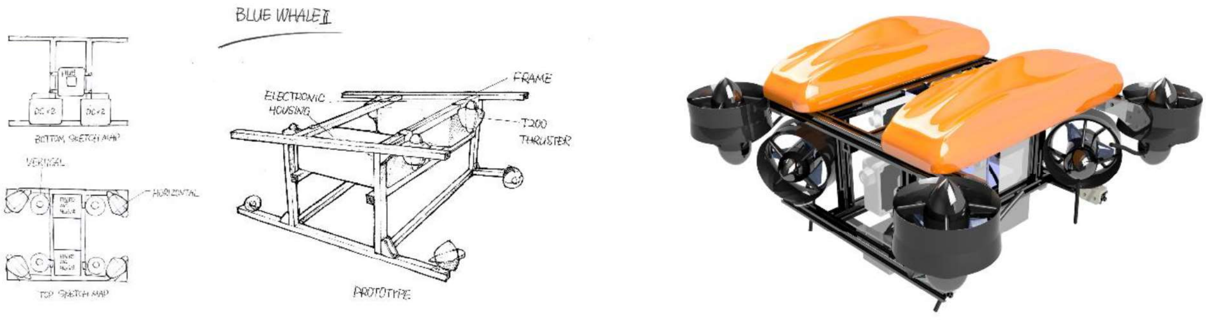


***Figure 3*** *Conceptual designs*

The design of the Blue Whale II contains two parts, one of which is the prototype for addressing the issues of movement and auto-adjust attitude of the vehicle underwater like automatic-holding, depth-holding and head-holding. The prototype is made up of mechanical frame, buoyancy, electronic system and software development. Another part is the design of external component, which consists of the devices related to the requirements like manipulator, wifi module and band tape.

## B. Theme

The original intention of Blue Whale series was to raise public attention of protecting blue whales and improving their living condition. This year's ROV is entrusted with new connotation. As blue whale means power and significance, we hope our ROV could complete various tasks in complicated underwater environment. Meanwhile, the blue whale, ancient species, is also a witness to human history. Thus, the Blue Whale series, especially the Blue Whale II, are expected to help humans find historical sites that have long been buried underwater. As described in the requirement proposal, the Blue Whale II can help customers explore and salvage underwater wreckage and discover those forgotten memories.

## C. System Interconnection Diagrams

The following are the SIDs of Blue Whale II's pneumatic system and electronic system.

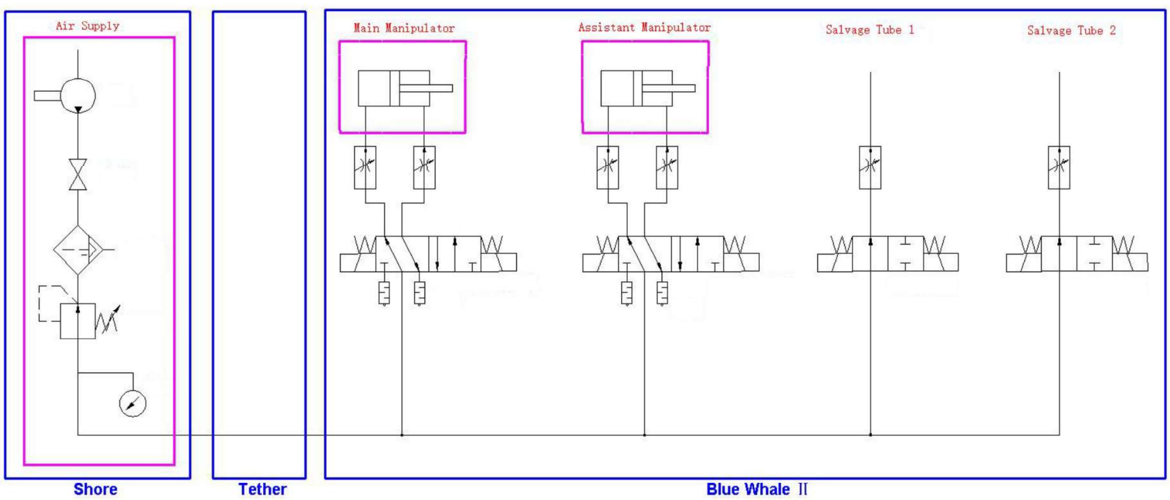


***Figure 4*** *Pneumatics system interconnection diagram*

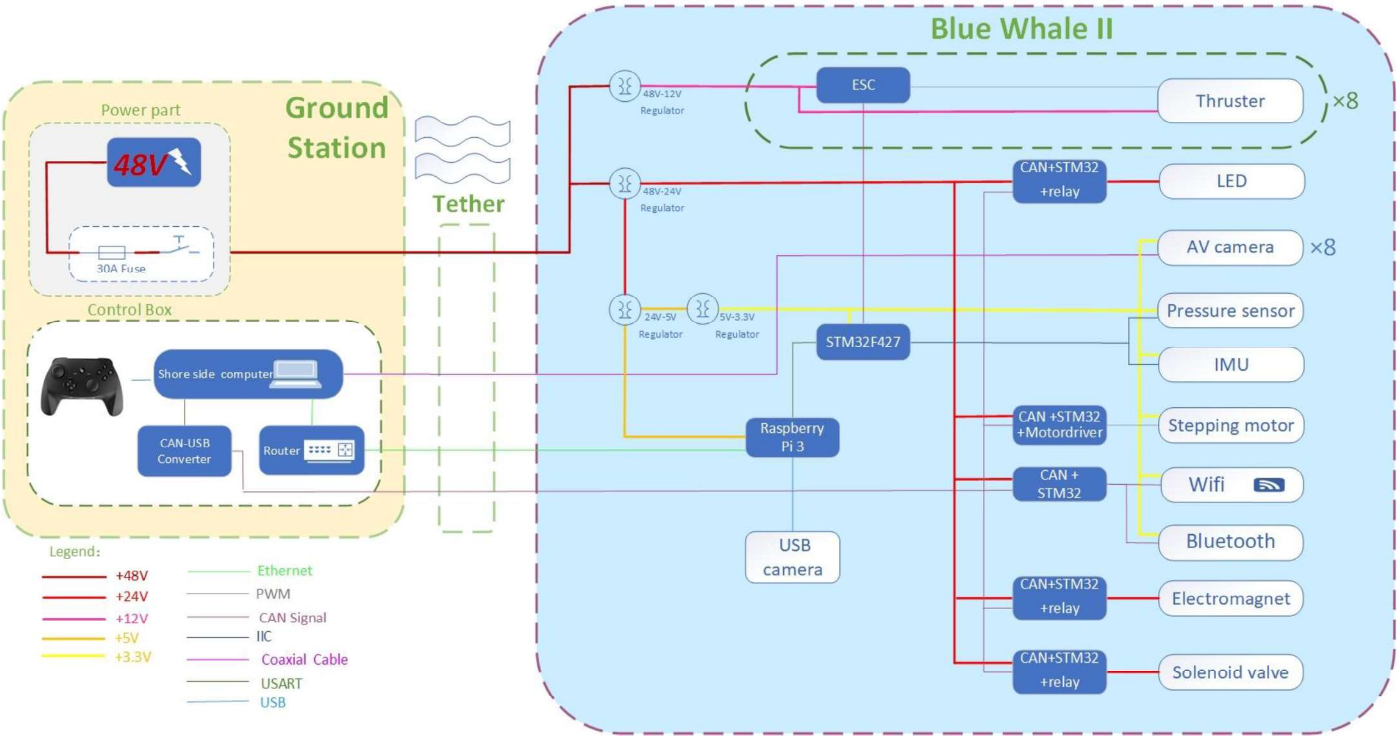


*Figure 5 Electronic system interconnection diagram*

## D. Prototype

The prototype is essential to Blue Whale II. It includes mechanical frame, buoyancy boards, electronic housing, dynamical system, and electronic system which contains communication system, energy system, and control system. It also includes the corresponding software development.

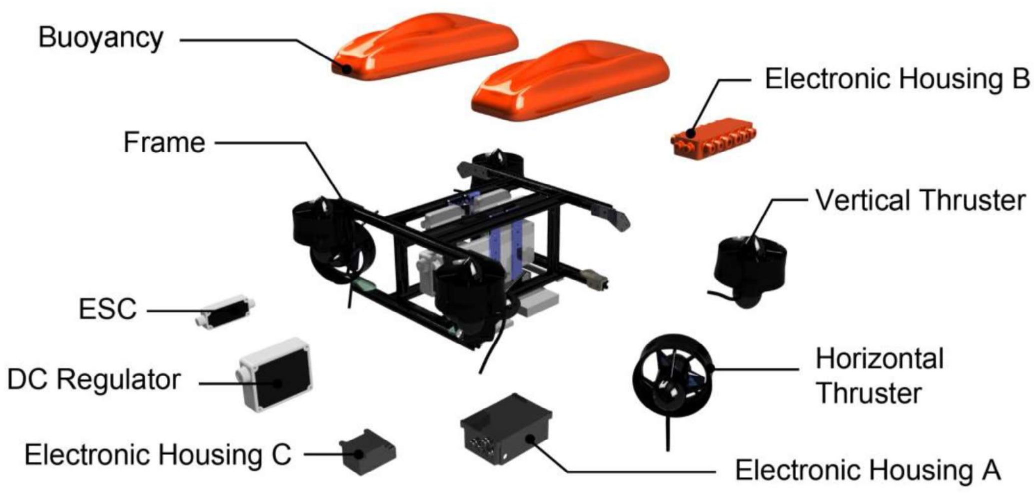


*Figure 6 Exploded-view drawing of Blue Whale II*

### 1. Mechanical

#### (1) Frame

Different from Type 2020 aluminum alloy used last year, the frame of Blue Whale II is machined from Type 1515 aluminum alloy. Although the mechanical strength of Type 2020 aluminum alloy [1], which can withstand a pressure of 300 MPa, is greater than that of Type 1515, it is unnecessary for the frame to bear such a high pressure as it only needs to withstand the weight of

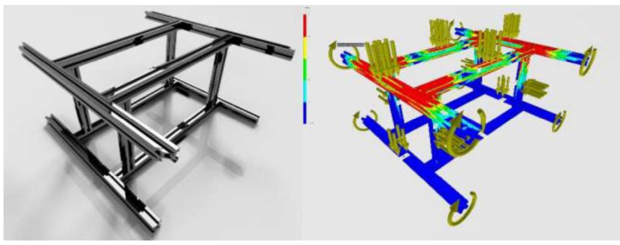

*Figure 7 Rendering of Blue Whale's frame and pressure analysis of mechanical frame*

the ROV. Therefore, we have chosen Type 1515 aluminum alloy. We lightened the frame after stress analysis. The weight of the frame of Blue Whale I is 7 kg, while that of Blue Whale II is mere 1.2 kg. After being oxidized and painted, it turns to be corrosion resistant, which extends its service life.

**(2) Buoyancy**

The main functions of ROV's buoyancy boards can be illustrated as follows: providing buoyancy for ROV, reducing the effects of water resistance during its movement and improving the stability of the vehicle [2]. Therefore, the design of Blue Whale II's buoyancy boards focuses on these functions.

The buoyancy board designed by Riverstone is made from two materials. The buoyancy material used on Blue Whale I is epoxy resin that has high hardness and is easy to process. However, the density of it is 500 kg/m^3, half that of water, which means the buoyancy ROV needs is equal to the weight of the buoyancy material. This made Blue Whale I too heavy. And polyurethane foam was applied to Riverstone's Challenger series ROV. Its density is less than that of epoxy resin but it is comparatively soft and will deform by the pressure underwater, which makes the buoyancy not constant. As a result, we made an innovative attempt by designing a composite buoyancy board of epoxy resin and polyurethane material. The buoyancy shell is made from epoxy resin and a buoyancy block made from polyurethane material is embedded in the shell. In this way, we not only decrease the overall density of the buoyancy board, but also retain the hardness of epoxy resin. The density of our buoyancy board is only 300 kg/m^3, but it can provide stable buoyancy underwater.

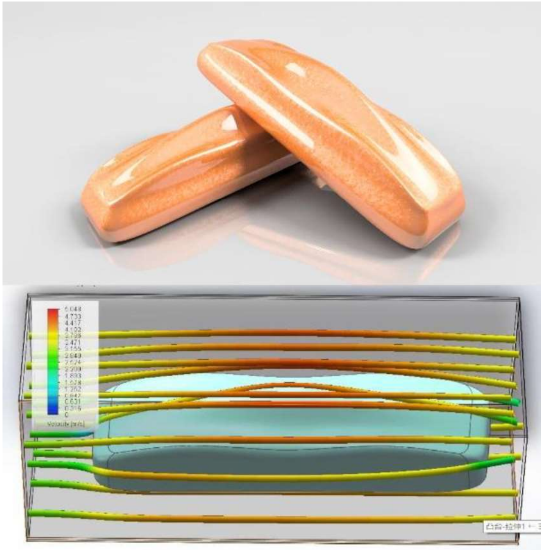

***Figure 8*** *Buoyancy & Fluid analysis*

The buoyancy board of Blue Whale II was independently manufactured by Riverstone from material manufacturing, shape design to material processing. Material producers developed the raw material formulation based on target parameters such as material density and hardness, and used molds to make epoxy resin and polyurethane blanks. Designers devised the shape of the buoyancy based on the required buoyancy of the ROV and fluid resistance. When design drawings and processing blanks were available, processors machined the material through CNC milling and made two pieces of material fit together. In addition, surface coating technology was employed, improving the corrosion resistance of the buoyancy and making the surface of it smoother, which further reduces the surface friction coefficient of the buoyancy.

**(3) Dynamical System**

Similar to the previous generation of ROV-Challenger, the Blue Whale series still adopt the standard layout of eight thrusters, which gives the ROV an omnidirectional movement capability. As is depicted in the picture, not only can it move backward and forward, left and right, up and down and turn left and right, but also can remain still in the three angles of yaw, pitch and roll because of the static balance of the robot itself, the use of IMU and pressure sensor. High-degree-of-freedom underwater robots can perform tasks more flexibly [3].

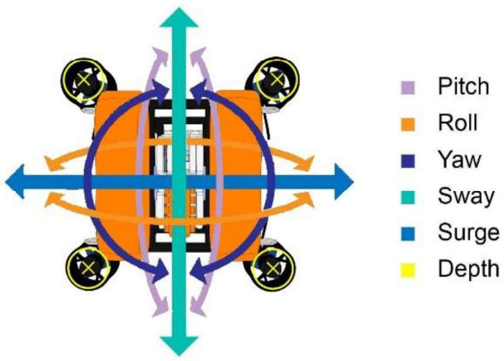


***Figure 9*** *Blue Whale's six degrees of freedom*

However, we replaced M200 thrusters with more powerful T200 thrusters. We used to use M200 thrusters as the source of power because they are cheap and easy to control. Although M200 thrusters operate steadily, limited power is provided. They can provide 2.2kg of thrust at 16V operating voltage. We hope to increase the thrust by means of boosting, but when M200 thrusters are operated at a voltage higher than 20V, revolving speed will be reduced and the thrust provided will be drastically decreased. T200 thrusters, on the other hand, can provide up to 4.98 kg of thrust at 16V operating voltage. At the same working voltage, their working capacity is twice that of M200 thrusters. This is the main reason why T200 thrusters are selected. Although the price is high, it is worth the money.

**(4) Electronic Housing**

The electronic housing is an important component of the ROV. This year, it is upgraded. The pressure tank was abandoned and was replaced with three separate electronic housings. When we originally designed Blue Whale I, we found that some components had a high failure rate, so it is necessary to dismantle the pressure tank frequently. However, dismantling will pose a threat to the waterproofness of the tank. In particular, several serious water leakage accidents resulted from the fatigue of the O-ring due to frequent disassembly, which caused water to seep into the tiny breakages of these rubber rings. The ROV eventually activated the self-protection program and disconnected the power supply of control system. Moreover, the electronic housing occupied much interior space inside the frame, making the task components only installable outside the frame. Although such design could realize desired functions, it was not aesthetic. This time, the subsystems of the electronic system are individually installed in different electronic housings instead of all in a large one. This leaves the interior of the frame more room for task components. Blue Whale II has also become more compact and beautiful.

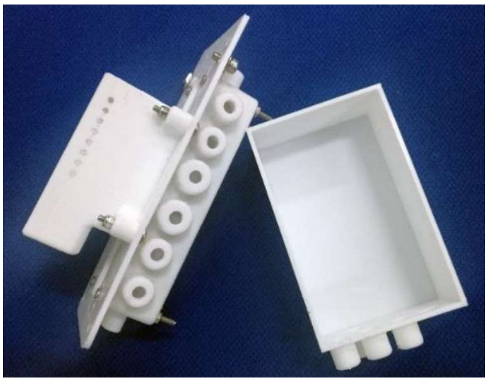

*Figure 10 Electronic Housing*

Blue Whale II's electronic system components are installed in three electronic housings. The first electronic housing is used to install Blue Whale II’s motion control system, including a Raspberry Pi and an STM32 microcontroller to control the space motion of Blue Whale II. Inside the second electronic housing is Blue Whale II's energy system used to provide power for Blue Whale II's electronic devices. The third one is Blue Whale II’s task component control box, which is used to control Blue Whale II's actuators other than the motion control system, such as manipulators and electromagnets.

**2. Electronic**

**(1) Introduction**

The electronic system of Blue Whale II mainly includes ground station, energy system, communication system, control system, sensors, and tether, which are also the most central parts of the Blue Whale II. Because they aim to provide power for electronic devices, while ensuring constant communication between various electronic devices. On this basis, the Blue Whale II control system was constructed and its space motion and underwater operations were achieved.

**(2) Ground Station & Control Box**

The ground station control box mainly provides power management for the Blue Whale series ROV. Inside the control box is an emergency stop switch, an input power switch, an output power switch, a current and voltage meter and a fuse. The main interface includes the input power interface, ROV tether interface and a network interface.

The Blue Whale II control box is the same as that of Blue Whale I, which is to improve the system compatibility of the vehicle. Different from Riverstone's early designed ROV--Challenger, we replaced its integrated control box which included power management and underwater robot operation. Because we found that the requirements from customers vary, and it was necessary to customize the ROV functions according to different requirements. Moreover, Riverstone needed to design a matching control box, which would distract the members from concentrating on the design of the ROV. Therefore, Riverstone adopted the current ground control program. In this program, the control box is only responsible for power management and users can access ROV communication system through the Ethernet interface on the control box and control ROV through their own computer. Then, Riverstone only needs to issue customized ROV operation software to meet different requirements.

The Blue Whale series control box is designed based on the safe operation flowchart released by Riverstone. The interface of input power and ROV tether have strain relief devices and anti-reverse housings. This is to prevent poor contact between the joints caused by dragging and loss caused by misconnection. Each of the input interface and the output interface has a key switch for managing input and output power. When the input power cord and the tether are connected, and the input power switch is turned on, the current voltmeter starts to display the input voltage. When the output power switch is turned on, the ROV starts to work and the current voltmeter will display the vehicle's operating current. The control box also has an emergency stop switch for emergency disconnection of power.

Riverstone will customize ROV's operating software according to customers' needs. In order to improve the operability of the vehicle, the operating software of the Blue Whale ROV comes with a graphical user interface and can be controlled by a joystick. Riverstone recommends that customers use the XBox 360 joystick because it feels good and has enormous functions. After the ROV is switched on, the customer connects the computer with a network cable to the network interface in the control box, and opens the operating software to see ROV parameters such as attitude, temperature, humidity, current, and underwater images in real time, and controls ROV movement through the joystick, which is very convenient.

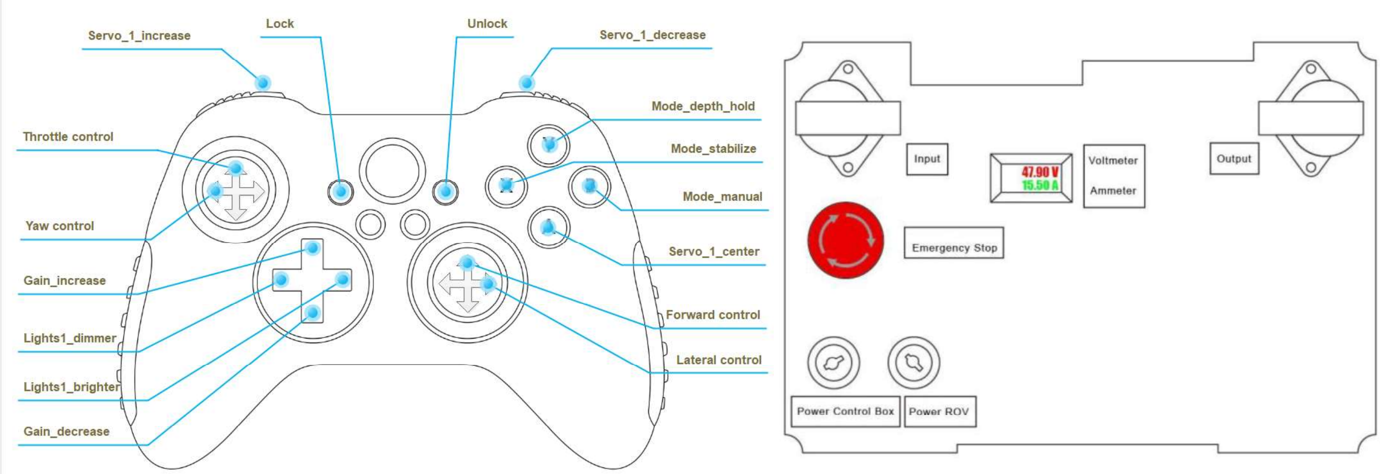


*Figure 11 Functional diagram of joystick and the diagram of power supply*

## (3) Energy System

Blue Whale II's energy system is the same as last year's for its stable operation after repeated experiments.

Blue Whale II's energy system consists of seven DC-DC voltage regulators, fuses, and an onboard power manager inside the electronic housing. Each voltage conversion module has its own fuse, and the fuses' specifications are determined through performance calculation. Blue Whale II's voltage conversion module includes four 48V-12V DC regulators, one 48V-24V DC regulator, one 24V-5V DC regulator and one 5V-3.3V DC regulator. These voltage regulators are able to provide transient high-voltage protection, over-current protection and over-temperature protection. The output voltage is stable and the voltage ripple is lower than 40 mV. They are adaptable to temperature and can work continuously in temperatures from minus 40 to 85 degrees Celsius.

| Device | Voltage/V | Max Current/A | Max Power/Unit | Quantity | Max Power/W |
|---|---|---|---|---|---|
| Raspberry pi | 5 | 2 | 10 | 1 | 10 |
| Peripheral Controller Board | 12 | 0.23 | 2.8 | 1 | 2.8 |
| Digital Camera | 12 | 0.5 | 6 | 3 | 18 |
| AV Camer | 5 | 0.1 | 0.5 | 4 | 2 |
| Stepping Motor | | | | 1 | 30 |
| Light Board | 5 | 0.3 | 1.5 | 2 | 3 |
| Underwater Astigmatism Lamp | 12 | 0.8 | 10 | 1 | 10 |
| Switch | 5 | 0.6 | 3 | 1 | 3 |
| Brushless Motor | 14 | 7 | 98 | 8 | 784 |
| Relay | 5 | 0.09 | 0.45 | 1 | 0.45 |
| Pressure sensor | 3.3 | 0.01 | 0.033 | 1 | 0.033 |
| Compass | 3.3 | 0.01 | 0.033 | 1 | 0.033 |
| | | | | | |
| Peak Power Available on Tether,W(48V + 20A) | | | | | 931.76 |
| Power Loss Due to Wires &Cables Resistance,W | | | | | 31.6 |
| Peak Power Available to ROV,W | | | | | 900.16 |
| Max DC Converter Efficiency | | | | | 97% |
| Power Loss W(Peak Rpv Power/Efficiency) | | | | | 27 |
| Peak Power After Conversion,W | | | | | 873.156 |
| Fuse current,A | | | | | 30 |

*Figure 12 Table of power calculation of Blue Whale II*

The onshore control box is connected to the input power cord and the tether, and when the power control switch is turned off, the control box starts to power the blue whale through the tether. After the power cord in the tether enters Blue Whale II, it is connected via a splitter to a 48V-24V DC regulator and four 48V-

12V DC regulators. Each 48V-12V DC regulator provides power for two thrusters and the corresponding electronic speed controllers. The 48V-24V DC regulator provides power for the devices on the CAN bus, including the stepping motor, circuits of the stepping motor, Bluetooth and WIFI modules, electromagnets and solenoid valves. The 48V-24V DC regulator is also connected to a 24V-5V DC regulator, which powers a Raspberry Pi and an STM32 microcontroller. The 24V-5V DC regulator is connected to a 5V-3.3V DC regulator as well, which powers the pressure sensor, electronic compass and 8 analog cameras.

**(4) Communication System**

Blue Whale II is equipped with a communication system made up of a router, a Raspberry Pi, STM32 microcontrollers, wireless communication modules, and video capture cards. Network communication, wireless communication, serial communication, IIC bus communication, CAN bus communication and analog communication are included.

The computer and router on the ground station are connected with the Raspberry Pi through the data cable in the tether. One STM32 is responsible for the space motion and attitude control of the Blue Whale II. It connects to the Raspberry Pi through a serial port and connects to an IMU and a pressure sensor through the IIC bus. In addition, the control signal lines of the eight electronic speed controllers are also connected to it. This microcontroller controls the electronic speed controllers to drive eight thrusters to rotate by outputting PWM signal. The Raspberry Pi also has a USB camera for underwater image recognition. All other analog cameras are connected to the ground station's video capture card through an analog signal line in the tether. All other devices are linked to the CAN bus and connected to the bus controller in the ground station via the CAN bus communication line in the tether. These devices are stepping motor, light strips, Bluetooth module, WIFI module, electromagnets and solenoid valves. In the design of Blue Whale I, we adopted RS485 bus communication, but it was eventually abandoned for its poor anti-interference ability and low transmission rate. Having considered about this, we selected Can bus because it has the characteristics of long transmission distance, fast transmission speed and strong anti-interference ability. The use of the Can bus can not only effectively control these devices, but also shows that the Blue Whale II has extremely strong scalability as many additional sensors can be based on the CAN bus for ocean exploration, underwater archeology and underwater construction.

**(5) Sensors**

**Camera**

When designing the Blue Whale I, we gave up on the underwater vision system of the previous generation, which used only analog cameras to monitor the underwater working area. Instead, cameras used were all digital. However, we found that although the digital camera image was clearer, the latency was higher than that of the analog camera, the DAHUA IP camera we used last year had a delay of about 500ms. For this reason, the pilot repeatedly criticized the camera of Blue Whale I. This year, we adopted an underwater monitoring solution that combined analog cameras with digital cameras. Digital cameras are used for image processing such as identifying the rear wing of the aircraft. Analog cameras are used to provide the pilot and the manipulator operator with a clear perspective. This design improves the operability of the Blue Whale II, otherwise the pilots and manipulator operators cannot make rapid judgments regarding underwater emergencies.

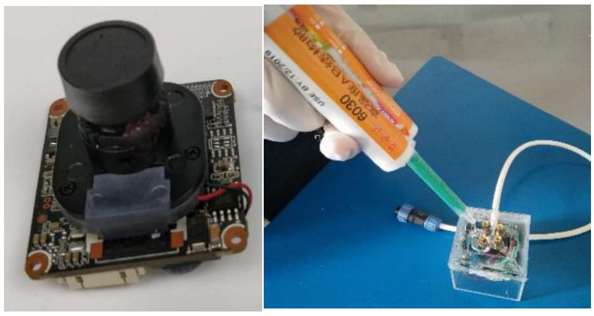

*Figure 13* Camera

**Inertial Measurement Unit (IMU)**

IMU is the key component of ROV. Without IMU, the robot can only rely on its force distribution to maintain balance. IMU has always been such an ROV sensor that we have difficulty selecting and optimizing. Last year, the company chose the MPU 6000 IMU which is commonly used by civilian drones. However, the MPU6000 is not precise when doing accumulative calculation [4]. For example, the cumulative error of the angle for ten minutes can amount to 0.045 degrees, which poses a great threat to the auto-equilibrium function of Blue Whale I. Particularly, when the Blue Whale I's turning speed is too fast, the vehicle has the potential to ride out of control. Compared to MPU6000, JY-61 has an acceleration resolution of 6.1e-5g and an angular velocity resolution of 7.6e-3 degrees/s. After leaving the JY-61 sensor for ten minutes, the angle cumulative error could only be 0.012 degrees, which is smaller than MPU6000. Meanwhile, JY-61 is embedded with Kalman filter, which benefits measurement accuracy to a larger extent. When using JY-61, the improvement of the sport stability of Blue Whale II compared to Blue Whale I is obvious.


***Figure 14*** *IMU*

**Pressure Sensor**

Blue Whale ROVs are all equipped with MS5837-30BA pressure sensors. Compared with the MIK-P260 pressure sensor used in Blue Whale I, this one has higher accuracy and lower power consumption. Its power consumption is only 30% that of the MIK-P260, and more importantly, it has a resolution of 0.2 mbar, which means it can distinguish changes of water depth within 2mm. while the MIK-P260 error will reach up to 20 cm, which is ten times that of MS5837-30BA. And the data resolution of MS5837-20BA will be further improved after filtering. Because of it, the Blue Whale II is able to achieve steady depth-holding. Similarly, we can use it to realize height measurement, as described in the requirement proposal.

***Figure 15*** *pressure sensor*

**(7) Tether**

The Blue Whale II tether is composed of sheath, a power cord, two network cables and an air tube. The sheath can prevent the cable from abrasion. The specification of the power cord is 16 AWG because it is rated for a maximum current of 30 amps. In a network cable, four cords are used as network communication lines and four as Can bus signal lines. Theoretically, the Can bus can work with only two signal lines, but we use four and combine two into a single wire, which reduces resistance and noise of the signal line, making Can Bus communication become more stable. We also use a network cable, which is the analog camera' s signal line. Considering the complexity of using 8 analog camera signal lines, we thought that we could use a CAT6 network cable instead of 8 separate analog signal lines. In this way, the manufacture of the entire tether will become easier, and because of the good anti-interference ability of CAT6, the noise of the analog signal is reduced to a large extent, and clear underwater images provided by the analog cameras can be seen on the ground station. Unlike Blue Whale I, Blue Whale II has only one air tube because solenoid valves are used. Originally, if we need to control multiple pneumatic manipulators, each arm would need two air tubes. The increase of the air tube increases the bending radius of the tether, thereby affecting the motion ability of the underwater robot. However, with the solenoid valve, only one air tube is required in the tether to meet the requirements. And such design reduces the weight of the tether, which used to be 20 m long and weighed about 4 kg. The tether of Blue Whale II is the same in length, but the weight is only 2.4 kg, which is almost half that of the original.

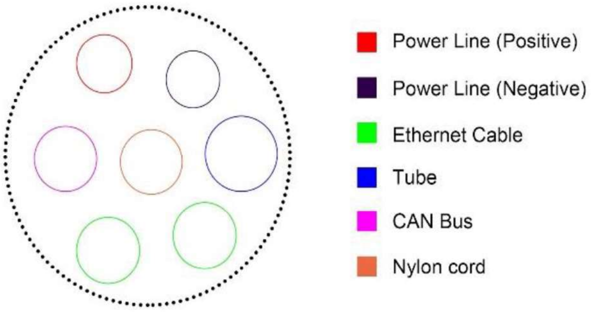


***Figure 16*** *Internal structure of Tether*

## 3. Software

### (1) Introduction

The design and compiling of Blue Whale II software is based on the electronic system. The sensors' data and control instructions transmitted from the computer should be received and executed by the ground station to control the stepping motor, thrusters, LEDs and other devices.

### (2) Control System

Operators on the ground station control Blue Whale II through a joystick while the operating software on the ground station sends control instructions to the Raspberry Pi in the electronic housing by monitoring the condition of the joystick buttons as well as the axis. Then, The Raspberry Pi parses these control instructions and sends commands to the next controller, such as an STM32 microcontroller. Next is the demonstration of such a whole operation--when controlling forward movement of the vehicle, the pilot pushes a joystick to operate the software in the ground station computer to send the joystick data to the Raspberry Pi. After the Raspberry Pi receives the signals for forward movement, it will send control commands through the serial port to the STM32 microcontroller. After the STM32 MCU receives the control data, it will immediately parse the control command into the PWM data that controls the rotation of thrusters. The thrusters' electronic speed controllers will take control of their rotation after receiving the PWM data. The four thrusters installed horizontally will rotate forward simultaneously. The rotational speed is theoretically in proportion to the position of the joystick. The stepping motor and LEDs are controlled in the same way as the thrusters.

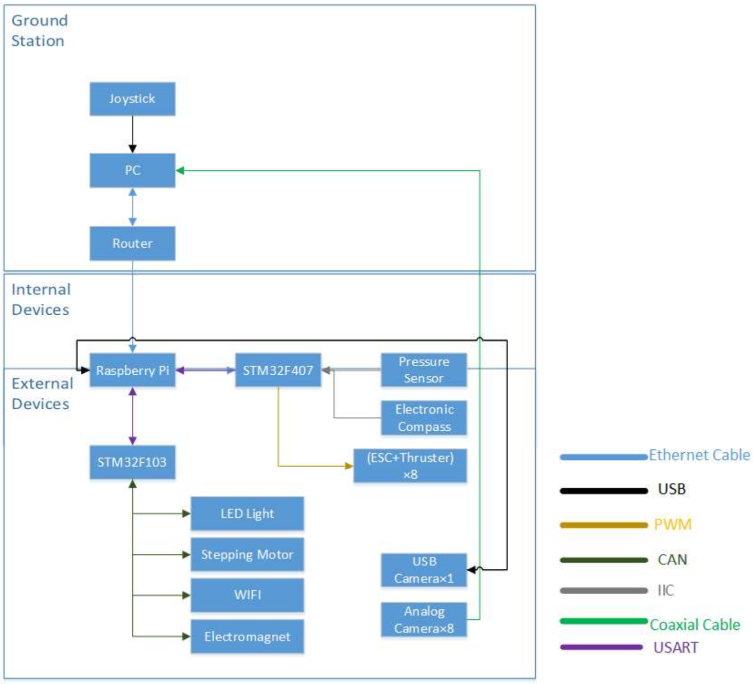


*Figure 17 Blue Whale software architecture*

In addition, Blue Whale II will also send data to the ground station's computer, including video streaming, attitude, altitude, the LED stepping motor, current status of the thruster, and current, temperature and humidity in housing. The data is sent to the ground station's computer through Blue Whale II's communication system and displayed in GUI.

Blue Whale II continues to use the core control algorithm of Blue Whale I, which was tested to be stable. This part of the algorithm code mainly realizes the attitude maintenance and depth movement of the Blue Whale underwater robots. This is a reliable algorithm of closed loop control, which is called PID control algorithm [5].

### (3) Graphical User Interface (GUI)

The software division developed an interactive GUI with the combination of C# language and WPF (Windows Presentation Foundation). Its key function is to provide Blue Whale II with sensor data and manipulate Blue Whale II's movement. The interface can display some attitude data, including the pitch angle and yaw angle as well as underwater images, movement depth, housing temperature and humidity. The network communication and button functions of the joystick can also be configured. Meanwhile, it can also directly control the external components of Blue Whale II, such as the communication among level turners, LEDs, WIFI modules, lift bags and OBS. According to the requirements, the GUI also contains drawing and image recognition functions, displaying the OBS data via WIFI and identifying the rear wing of the aircraft

The UGC used last year was designed on the basis of Unity3D, a ground station software with the operation principle of game physics engine. This UGC can be called by GUI. For some improvements, we cancelled the part of ROV operation but retained the simulation part. Although UGC is more interactive, the pilot of Blue Whale II does not need such rich visual effects. Instead, as much data as possible is expected to be displayed. This is to improve practicality rather than visual effects. When UGC is called by GUI, the joystick can be operated to control the virtual ROV in UGC. This feature has also been used by Riverstone in product promotion and ROV pilot training.

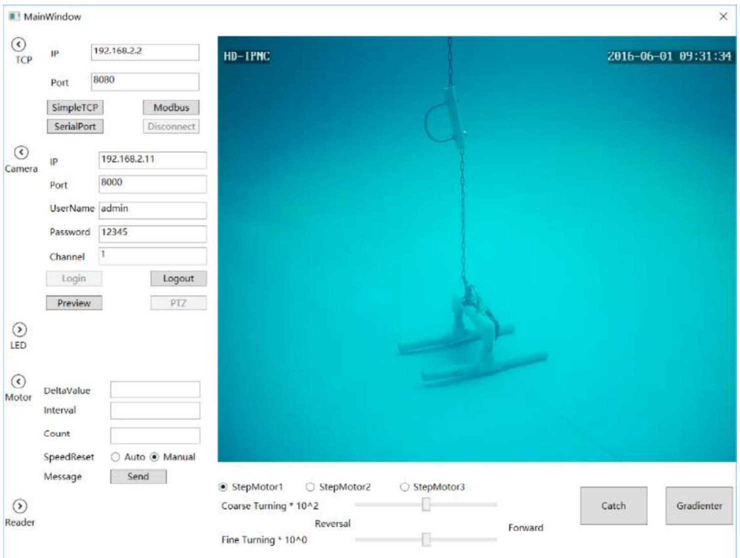


***Figure 18 GUI***

### E. Mission Specific Features

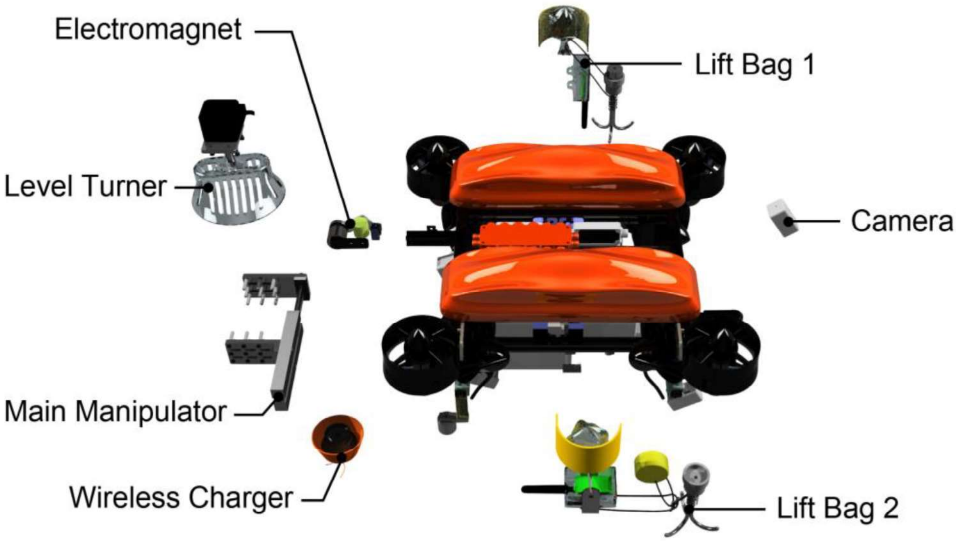


***Figure 19*** *Mission specific features of Blue Whale II*

### 1. Aircraft

#### Image Recognition

Blue Whale II uses a digital camera to take underwater images and the OpenCV image processing library for image analysis and target recognition. We determine the shape of the airplane's tail model by judging the number of graph points, that is, whether the target image shape is quadrilateral or triangular. We use Image Space Conversion to recognize the color of the target image. The RGB color space images captured by the cameras are converted into HSI [6] color space images because in HSI system, colors are defined by hue, saturation, and brightness rather than three primary colours- R, G, B. By using HSI, color recognition can be better implemented. Moreover, we can analyses the ID of the airplane’s tail model by judging the colour and shape. Combining with the noise reduction and edge detection algorithms, we can further improve the accuracy of target recognition.


***Figure 20*** *Output of Image Recognition*

## Lift Bag

The lift bag consists of an inflated bag, an electronic housing and a hook at its bottom. Inside the electronic housing there is a microcontroller, a wifi module and an electromagnet. First, we install an air pipe into the inflated bag, then the lift bag is clamped and fixed to the target objective. Next, air will be pressed into the lift bag through the air pipe. While releasing the lift bag, Blue Whale II will receive the message from the lift bag through wifi and then send a release signal. After receiving the signal, the lift bag will turn off the electromagnet. Finally, the lift bag will detach from the target object by its gravity and then return to the surface.

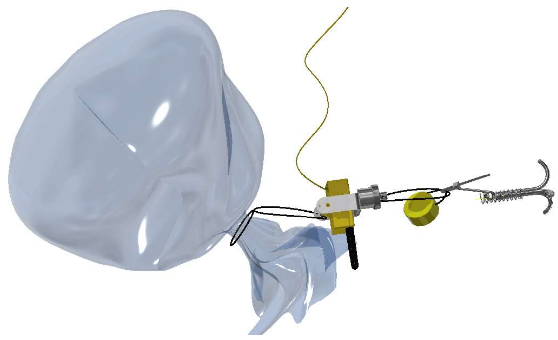

***Figure 21*** *Lift bag*

## 2. Earthquakes

### Wireless Charger

Riverstone designed a wireless charging device that can supply power to OBS. It consists of a fuse, a magnetic reed switch, a tether, a mutual inductor and an electronic housing. Electronic devices are fixed in the housing and sealed by epoxy. The housing, designed according to the shape of the wireless charger socket provided by OBS, can perfectly fit in with it and supply power. The wireless charger uses ground power supply and is connected to the control box through an independent tether using an Anderson connector. It can be held by the electromagnet on the vehicle, transported to and installed on the socket by pilot's operation of Blue Whale II. Then, the electromagnet is powered off and the wireless charger is successfully installed.

***Figure 22*** *Wireless Charger*

### WIFI Module

Our company connects the ESP8266 WIFI module with the WIFI module in OBS. The WIFI module is connected with the Can bus through an STM32 microcontroller. Http is applied to collect IMU data from OBS while the WIFI module is connected to the STM32 microcontroller through the serial port and it will send the received data to the STM32 microcontroller. Then, the STM32 microcontroller will transfer the data into Can bus signal. After the bus controller on the ground station receives the signal, it will send the data which will then be displayed on GUI to the computer through the serial port. After OBS is adjusted to the horizontal state, OBS data will be received by the same way. The GUI will plot the received data into the coordinate system and the amplitude-time graph.

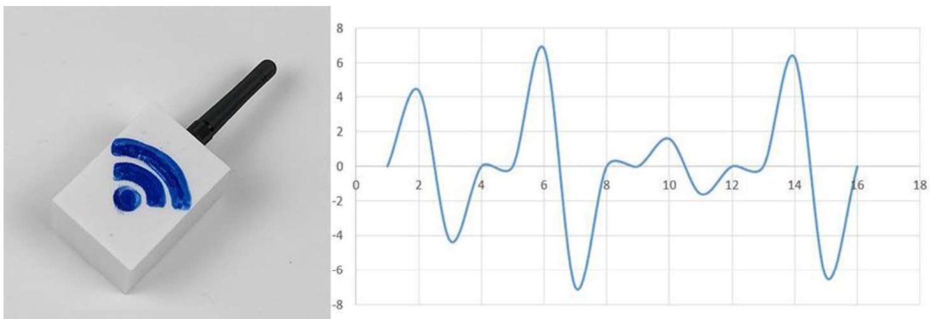


***Figure 23*** *WIFI Module and Amplitude-time graph*

### Level Turner

Blue Whale II will use a waterproof stepping motor to drive a grille made by 3D printer to rotate the OBS leveling device because the number and speed of revolutions of the stepping motor are controllable. The net cover is designed in the shape of a bell mouth, so that regardless of the initial angle of lever turner, as long as the net cover covers the level turner and the stepping motor drives the net cover to rotate, the net cover can always drive the horizontal adjusting device to rotate

***Figure 24*** *Level Turner*

with the stepping motor. This enables Blue Whale II to be more convenient and efficient for horizontal adjustment.

### 3. Energy

#### Main Machine Arm

According to the description in the requirement book, we need to transport and install underwater turbine generator. Based on the former experience, the main manipulator designed for the Blue Whale II is constituted by a gripper driven by air. Besides, we installed 10 electromagnets as suspension points. The generator base is held by pneumatic grippers and fixed onto Blue Whale II by electromagnets. After the tools are transferred to the designated area, the base will be placed first, followed by fixing the generator unit onto the base through the auxiliary devices. There is another auxiliary mechanism on the side of Blue Whale II, which leans against the latching mechanism of the turbine generator. Thus, the Blue Whale II can drive the locking mechanism and finally lock the turbine generator.

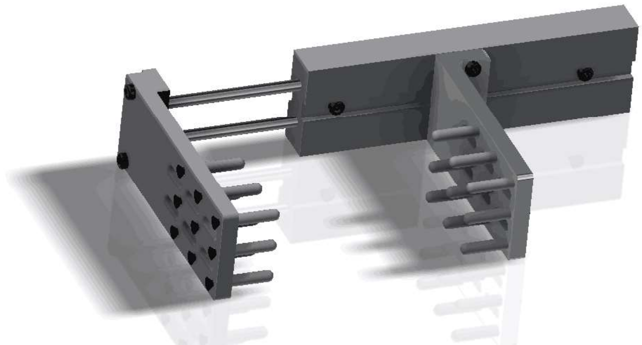

***Figure 25*** *Main Machine Arm*

I-AMP is fixed through electromagnet below the machine. When Blue Whale II reaches the designed area, the I-AMP can be installed in the target area and release electromagnet. To facilitate the Blue Whale II to push the I-AMP's latch mechanism, there is a slope with a curved surface fixed at the edge of the auxiliary device directly under the main mechanical arm, which can lift the slightly sinking latch mechanism. Thus, the Blue Whale II can easily push the latch mechanism and lock the I-AMP.

At the back of Blue Whale II there is an electromagnet suspension point for fixing berthing base, after Blue Whale moving to the designated area and release electromagnet, the berthing base will be located at the pointed area.

#### Band Tape

The Blue Whale II will use the measuring tape on one side of the frame to measure the specified distance. There is a ring at the front of the measuring tape to catch the vertical pipe on the base of the turbine generator. Blue Whale II's backward movement can drive the measuring tape to move. Ground station operators read the measurement data from the image provided by the camera above the tape. Upon finishing the task, Blue Whale II will float, causing the ring to disengage from the base of the generator. Then, the measuring tape will be retrieved by the spring inside itself.

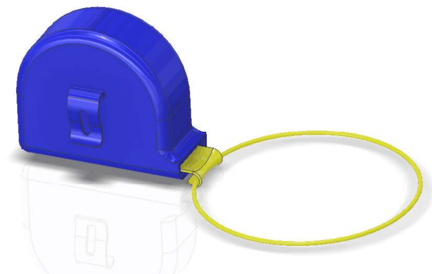

***Figure 26*** *Band Tape*

#### Depth Measurement

The pressure sensor is an important component of Blue Whale II, which help Blue Whale II achieve the function of both depth holding and water depth measurement [7]. By measuring P1, the bottom water pressure, and P2, the pressure of the area to be measured, we reached the conclusion that the absolute value of the two places' water pressure equals to the pressure difference between the area to be measured and the bottom. According to the formula $P=\rho gh$, the height between the area to be measured and the bottom is $|P2-P1|/\rho g$ [8].

#### Acoustic Doppler Velocimetry (ADV)

The ADV we innovated is a device easy to be installed with its weight underwater as -200g, which means that when there is no additional force upon the ROV, it will float to the surface instead of sinking to the bottom of the pool. Since the ADV is highly precise and costly, we expect that the ADV can return to the surface with its own buoyancy and be recycled successfully by the ground station operators even if

***Figure 27*** *ADV*

there is something wrong with the fixation. The ADV's hook is designed into a special shape like a clasp so that the vehicle can use the gripper of the manipulator to carry the ADV to the bottom, and float along the chain to the installation position. In this case, the hook on the ADV can be firmly stuck to the position, so that the ADV is fixed to the designated position.

## III. Safety

### A. Safety Philosophy

Riverstone has given top priority to the safety of its employees, and then the product. Because only if the safety of workers is ensured can the product safety of Blue Whale II be guaranteed. Safety accidents once happened and Riverstone has been strict with its employees to ensure safety ever since. The majority of safety accidents were caused by its employees' carelessness due to the fact that they were too familiar with their own work. Therefore, we believe that all accidents can be avoided as long as each employee complies with the established safety protocols and is supervised by the Safety Inspectors. As for less experienced employees, veterans are obliged to provide necessary guidance until they can work independently. All of these safety measures are taken to keep both employees and users safe.

### B. Safety Education

The safety education of Riverstone is divided into two major parts, one of which is the company's own safety instruction courses. Riverstone mandates that all employees participate in safety education courses and pass safety education examinations, including non-technical employees. As a result, more safety inspectors can be set for the company to supervise the operations of processing staff. The other part focuses entirely on the processing staff. Riverstone requires that all processing staff must hold occupational qualification certificates issued by the Ministry of Labor of the People's Republic of China, such as a fitter certificate, a lathe worker certificate and an electronic assembler certificate. We even require that the pilot of Blue Whale II hold a drone license issued by the Civil Aviation Association of the People's Republic of China. Holding these certificates means that the holders are familiar with not only the entire operation process and content of the work involved, but all the potential threats of these operations, as well as necessary precautions and protective measures. Operators should have a good knowledge of the safety requirements that the processed products must meet.

***Figure 28*** *Safety Education*

### C. Building Safety

Accidents are most likely to take place in the processing and assembly phase of ROV. Therefore, we are extremely strict with the workers involved in processing and assembling products. Riverstone stipulates that employees who do not hold relevant occupational qualification certificates issued by the Ministry of Labor of the People's Republic of China cannot carry out corresponding processing operations or use related tools during the operations of turning, milling, mechanical assembly, and electronic assembly. If a safety inspector discovers that an employee is playing with a tool for mechanical processing or electronic assembly, the employee and the leader of his department will be severely punished, even demoted or suspended.

Processors must comply with the safety protocols of relevant operations. Before entering the processing site, they must present to the safety inspector their ID cards, occupational qualification certificates and processing licenses with the company's seal. Only after the safety inspector checks their certificates can he open the safe, issue processing tools and protective equipment. And processors must be supervised and escorted by the safety inspector while processing. Firstly, necessary protective clothing must be inspected and worn before processing. For example, prior to the cutting process, the safety goggles and dust-proof masks must first be checked by the safety inspector before being handed over to operators. Then, processing staff must check the processing tools and have them rechecked by the safety inspector. Next, during processing operations, the safety inspector must accompany operators in the whole process. If an emergency should take place, the safety inspector must take immediate actions. For instance, in the event of a loss of control during the milling process, the safety inspector must immediately press the emergency stop button. After the processing is finished, processors must inspect the tools again and hand them over to the safety inspector for re-inspection. After the completion of re-inspection, processors need to transfer the tools and protective gears to the safety inspector for preservation. If some processor does not comply with the safety protocols, the safety inspector should report it to the CEO and penalize the personnel. The safety inspector should register the names, processing content and time of the processors each time. If the safety inspector is found to be dereliction of duty, he will be disciplined.

The punishment of processors or safety inspectors includes re-education of safety and safety assessment, deduction of occupational qualification certificates, cancellation of processing licenses or safety inspector qualifications issued by the company, downgrading or expulsion.

***Figure 29*** *Our employees, processing electronic housing, filling Epoxy resin and soldering a PCB*

**D. Product Safety Features**

We believe that the company's detailed and rigorous safety protocols and employees' firm safety awareness have contributed to the outstanding product safety features of Blue Whale II. In addition to the power safety button of the ground station, Blue Whale II has many safety features. Our machine has no sharp edges, and all thrusters are attached with protective nets and warning labels. Besides the necessary fuses, Blue Whale II has a power manager inside the electronic housing. The power manager controls all power conversion modules through electromagnetic relays. A current sensor is installed on the power manager to monitor the health status of Blue Whale II in real time. The ground station GUI will display the information in real time. When the temperature, humidity, or current in the electronic housing is higher than the warning value, the power manager will start the protection program, disconnect the power conversion module, and force the Blue Whale II to shut down. The power manager has a warning light. When the Blue Whale II is working normally, the LED on the power manager will keep green. If the temperature, humidity, or current is higher than the health value and is lower than the alert value, the LED lights up yellow. After the operation is over, the staff will start the inspection process, perform a complete maintenance of the machine and replace the device. If the LED lights up red, the operators will immediately recover Blue Whale II for emergency maintenance.

Our ROV, Blue Whale II, contains some materials which will pose a potential threat to the environment or the human body, such as polyethylene, epoxy, and PTFE. We used them to make 3D print, buoyancy and surface preparation. The components made by these materials will be harmful only when they are intentionally destroyed.

**E. Operation Safety**

Riverstone has always required that pilots of the Blue Whale series must strictly abide by the operational safety protocols. And before the operation of Blue Whale II, safety inspections must be performed, such as checking whether the screws are loose, whether the voltage and current are normal, and whether the pneumatic power is normal. Throughout the operation, the safety inspectors shall monitor the health data of Blue Whale II such as current and voltage, housing temperature and humidity. After the operation is completed, the Blue Whale II needs

***Figure 30*** *Unity Ground Control*

to be checked again. Please see the **appendices** for specific safety checklists. The pilot of Blue Whale II must hold a drone license issued by the Civil Aviation Association of the People's Republic of China. Anyone who does not hold a drone license cannot operate Blue Whale II. In addition, Blue Whale II will have a systematic safety check at regular intervals.

At the same time, before the pilot of Blue Whale II formally operates it, the process will also be simulated by UGC (Unity Ground Control) developed by the software division. Through the operation of the virtual ROV, the pilot can practice the operation process. Only when the pilot is familiar with the entire process can he formally operates Blue Whale II. This is also set for operation safety.

### F. Troubleshooting

A detailed set of troubleshooting flow charts have been developed to overhaul the ROV and check the source in the event of an unknown failure. Not only are they targeted at Blue Whale II, but also can be applied to other products designed by Riverstone. Troubleshooting flow charts are divided into electronic and mechanical parts. In terms of electronic examination, it requires the step-by-step check in all respects from energy, communication, control system to various task components. As to mechanical examination, it needs to check the gas-powered system, the frame, and the seal of the pressure-resistant housing if there exists one. Relevant charts are enclosed in the **Appendices**.

## IV. Project Management

### A. Company Composition

Riverstone is composed of three major departments: Technology, Financial Management and Marketing. Technology Department is mainly in charge of the design and manufacture of Blue Whale II. It consists of six sub-divisions, namely Machinery, Electronics, Software, Pilots and Safety Production. Mechanical division is responsible for the design and manufacture of buoyancy, mechanical frame, electronic housing, and power systems. Electronics division is responsible for the design and manufacture of electronic systems. Software division is in charge of writing GUI, STM32 microcontroller programs, and the code in Raspberry Pi. Pilot group consists of drone pilots, who are the drivers of Blue Whale II. Pilot group is the most important part of Technology Department in that the feedback from pilots is extremely important for the design and improvement of Blue Whale II. Safety Production Department mainly sees to supervise the safety of electronic system processing and machining. Financial Management comprises Finance, Purchasing and Property Management. It is mainly responsible for managing Riverstone's assets and purchasing materials. Marketing consists of Public Relations and Publicity. Its main works are accepting requirement documents and company advertising.

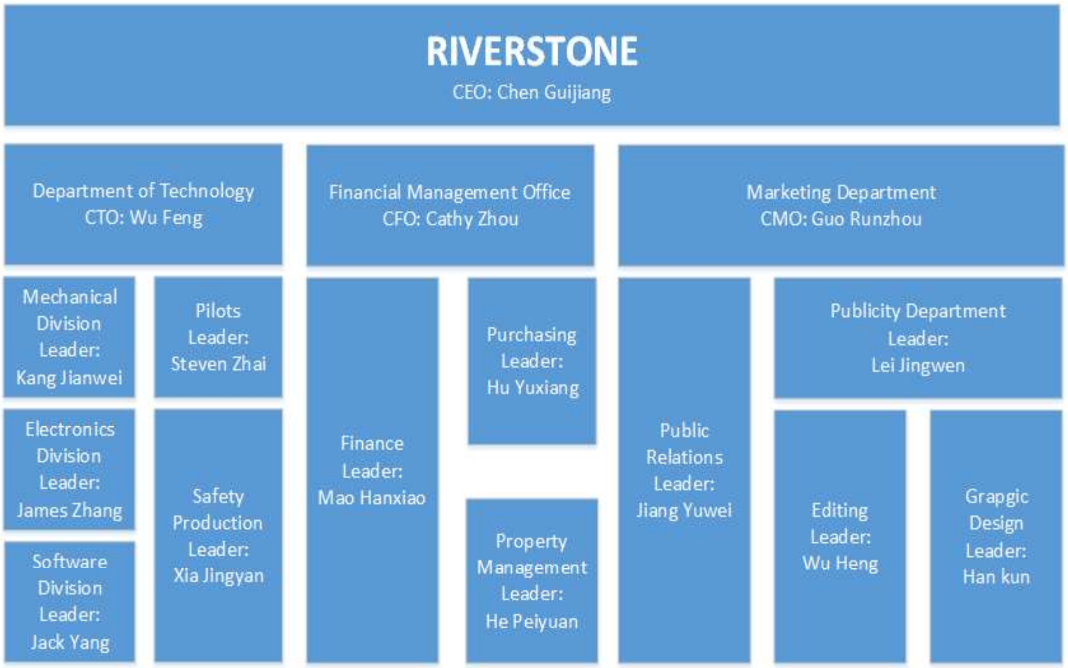


*Figure 31 Organizational structure*

In addition, Riverstone has also set up a management committee in order to ensure the normal work with CEO acting as chairperson and CTO, CFO and CMO as members. All the works are coordinated by the management committee. Our CEO will discuss with each member of the management committee about the construction tasks and acceptance goals. Each member of the management committee will refine the tasks for the relevant department based on these indicators and respectively send them to the Technical Department, Marketing Department, and Material Management Department. For instance, after the preliminary design proposal had been made, CEO issued the task of manufacturing ROV prototype at the committee meeting. Then, CTO will refine it into the construction tasks for the Technical Department. The mechanical group is responsible for the processing of the buoyancy and the construction of the frame. The electronic group takes the responsibility of designing, building and debugging circuit boards. The software group will write motion control algorithms and graphical user interfaces. After the construction of each group is completed, we will organize a system integration and test. All these tasks are posted on Teambition, and the group leader will update the tasks every day. Similarly, CFO and CMO will issue materials procurement and market research tasks to the Material Management Department and the Marketing Department to ensure that the Technical Department works properly. Because of this, the company can design a powerful ROV--Blue Whale II in such limited time.

### B. Financial Management

Riverstone's funding mainly comes from school's special funds. And project funding is mainly for the purchasing of electronic devices and machining materials, electronic system processing and machining. In order to save costs, we opt for inventory materials such as aluminum alloy profile, wires and so on. Besides, any purchase of materials must be examined and reviewed by CEO and CFO. Funds and materials are managed by special personnel, and expenditures are calculated on a weekly basis. We set up a section for Riverstone's Financial Management alone to control expenses. Please see the **Appendices** for the budgets and expenditures.

### C. Project schedule

Riverstone has a number of working groups. Generally, the CEO determines the task indicators. Then, CMO and CTO assign tasks to each group according to the task indicators. After that, group leaders assign tasks to each member. Moreover, Riverstone has officially adopted team collaboration software this year. Both document writing and software code writing are finished online. We assign specific tasks and monitor project progress through team collaboration software. When compared with the past, Riverstone's work efficiency has been significantly improved. We also use Gantt chart to coordinate the construction time of each group in order to ensure that the project design and processing are more efficient. A summary meeting is held each weekend, in which work for the following week is assigned according to the degree of accomplishment of work finished the week before. The Gantt chart is in the **Appendices**.

## V. Challenges

It is a real headache that we have the tight schedule because of various reasons. The overwhelming majority of our employees are appointed to the ROV projects suddenly so that they have to suspend or delay their original task. Furthermore, a number of employees even burn the midnight oil just to make sure that the task can be finished on time. Another challenge is that some employees have to learn the new skills and acquire knowledge of new subjects in a very short time, such as 3D printers and image processing algorithm.

### A. Technical Challenges

Riverstone used to select yellow LED lights as the main means of underwater lighting because of its excellent underwater lighting effect, good penetration, and the lighting distance that is about 20m. However, the absorption of light by the water and the uneven illumination will cause colorcasts and non-uniform brightness of the images captured by underwater cameras. If it just requires underwater lighting, these issues can be negligible, but in this year's demand book specifically stated that there is the must to identify the aircraft tail through image recognition. If the yellow-light LED lights is still as the only source of underwater lighting, the accuracy of image recognition will be badly affected.

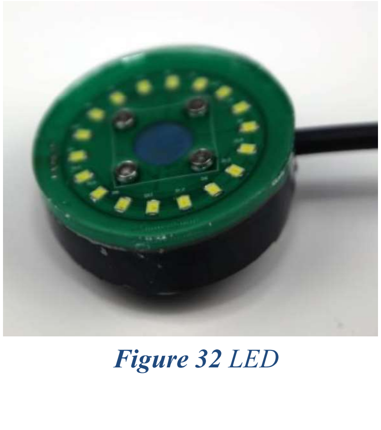

***Figure 32*** *LED*

Therefore, this year, Riverstone designed a white light LED lamp, which alleviates the problem of colorcasts and non-uniform brightness. Under this circumstance, there are two alternatives for Blue Whale II to choose in accordance with different work, namely yellow LED light and white LED light. For instance, the yellow LED light is on during the cruising state while in the operating state the white light LED is on and the yellow LED is off. Undoubtedly, such design of underwater lighting system improves the working capabilities of Blue Whale II.

**B. Non-Technical Challenges**

Compared with the design and construction of the Blue Whale I, it is apparent that this year we have a very tight schedule in the design and construction of the Blue Whale II. The notification of the commencement of the project is very sudden and we only have less than six weeks to carry out the project. It is the biggest challenge that Riverstone has ever confronted. However, with the help of the previous years' experience and reasonable time management, we still complete the construction of Blue Whale II in time. We assign the related tasks, monitor the process of project and financial management, collaborate on editing documents online and file sharing through the team collaboration software--Teambition. The employment of team collaboration software has greatly increased the productivity of Riverstone, and meanwhile reducing the probability of making mistakes in team management. Within less than six weeks, Riverstone's employees completed the mission that company took 16 weeks to complete in the previous year. Riverstone is very grateful to the employees for their hard work and perseverance.

## VI. Future Improvements

**A. Technical**

Although Riverstone has made progress in the transportation and installation of mission props, we have optimized the layout of the electronic system. However, there still exists room for further improvement. This year, we have adopted electromagnets to fix the mission props, but we can also use passive methods to transport mission props. For example, we can design some more ingenious mechanical structures so that props will be automatically separated from the machine after being accurately installed in designated locations instead of using electromagnet or the robotic arm. In that case, we can improve the efficiency of underwater operations.

The Blue Whale II has a high degree of freedom, but we have found some degrees of freedom of ROV not frequently used, such as left and right shifts. We also noticed that Blue Whale II needs to spend a lot of time cruising rather than underwater operating and Blue Whale II's thruster layout determines that its forward speed is the same as that of left and right. According to users' feedback, Blue Whale II does not have to excel in left and right shifts, so we hope to increase its cruising speed, which prompted us to find solutions to optimize the layout of the thruster. Initially, we just increased the voltage of the thruster to improve its capacity, but through calculations, we realized that the total capacity of the Blue Whale II would be much higher than the 1500w specified. Afterwards, we gradually discover that we can also change the layout of the original Blue Whale II thruster. The horizontal thruster mounting direction will be 30 degrees from the positive direction instead of the current 45 degrees. Based on the calculation, if the installation angle changes, the forward force provided by the thruster will become 1.22 times the original force, the left-right shift 0.7, and the steering force 0.86. Our ROV will have faster cruising speeds.

**B. Management**

Riverstone is a long-established company. Apart from developing ROV, we are also engaged in the design and manufacture of all-terrain vehicles, bionic robots, and drones. Although Riverstone fully believe in the capacity of its employees, it is embarrassing for them to undertake this temporary assignment of underwater robot research and development projects. They belonged to different R&D groups beforehand. For example, Zhang Jianpeng, leader of the electronics division of the Blue Whale II R&D Committee, originally belonged to the Intelligent All-terrain Vehicle R&D Committee. However, he suspended his R&D work and devoted himself to the design and processing of Blue Whale II electronic circuit after receiving the temporary appointment from the Riverstone Board of Directors. More examples can be seen among our employees. Riverstone cannot unconditionally ask employees to meet the needs of the company, so the company decided to increase the benefits and welfare of the employees in the next fiscal year, such as improving the accommodation environment of the employees, offering food coupons, and providing living allowances according to their work. Compared with the capital owned by Riverstone, these creative young talents are the company's most valuable asset.

## VII. Reflection & Lessons Learned

### A. Reflection

#### Chen Guijiang-CEO

I am honored and flattered to be the CEO of Riverstone and I am very grateful to MATE for providing this learning platform to improve our ability. For me, ROV is a new thing because I have been specializing in mechanical design and machining before the competition. As a result, numerous challenges such as team management and the organizing of the design, processing and assembly of the Blue Whale II confront me but I try my best to meet them. I view this competition as a great opportunity of learning and I look forward to communicating with various companies.

***Figure 33*** *Chen Guijiang(CEO) & Guo Runzhou(CMO)*

#### Kang Jianwei- the Mechanical Division Leader

***Figure 34*** *Kang Jianwei (Mechanical Division Leader)*

Although it is the second time I have participated in the MATE ROV Competition, I am still very stressed to be the leader of the mechanical division. Such a shift of role from an ordinary mechanical engineer to the leader of the mechanical division is challenging for me both psychologically and academically because I need to learn and master more knowledge and skills related to machining, such as the use of 3D printer and laser cutter. In the meantime, I need to organize effectively the work of the whole group rather than personal tasks. However, it is my honor to hold the position and I believe I am competent for it.

#### Zhang Jianpeng-the Electronics Division Leader

I am quite proud of being a member of Riverstone. As the leader of the electronics division, I am conscious of the great responsibility that falls on my shoulders. Any step should not be taken lightly, for it may be the key to success. In addition, I become fully aware of the importance of teamspirit in the process of working with other team members. Compared with the skills I have developed; what I value most is friendship.

***Figure 35*** *Zhang Jianpeng (Electronics Division Leader) & Wu Feng(CTO)*

### B. Lessons Learned

#### Technical

There was a lot of repetitious work in our previous designs. For example, in the first year, CAN bus was used but it was abandoned the next year because we think that RS485 is simpler to use than Can bus. However, the Can Bus was used again in the third year. These repeated efforts are not necessary because we need to consider to lay on which kind of bus based on specific occasion. Another example is about the cameras. There are some occasions where all cameras installed are analog cameras and also other occasions where analog cameras are completely replaced by digital cameras.

We were always looking for materials with low density and high hardness when designing buoyancy. However, we found the two characteristics are contradictory. We have not decided whether to use polyurethane materials or epoxy resin until someone suggested using the two materials together. So the composite buoyancy of Blue Whale II was produced successfully.

It has been proved that different technologies should be combined and we need to distinguish the applicable occasions. In other words, we can't always be tangled in getting the optimal solution in part, but to consider comprehensively, analyze the advantages and disadvantages, and get the global optimal solution.

**Team Cooperation**

Teambition, a team collaboration software, was used this year. In previous years, a lot of time had been wasted in paper office because of error correction of machining drawings, technical report and even financial management in the final stage of the project. Yet, these problems were solved by Teambition. As a result, the company should attach importance to not only technological innovation, but also innovative application of network technology in team management.

## VIII. Corporate Social Responsibility

Riverstone has always been committed to robotics education and new technology promotion. We target not only on schoolmates but also elementary and middle school students nearby. It is mutually beneficial as students who are interested in new technology will continue to delve into it to promote its development and Riverstone will ceaselessly attract new talents. For instance, Yang Chengbin, leader of the software division this year, volunteered to join Riverstone after participating in the ROV technical seminar held in May last year. Riverstone also holds technological innovation products exhibitions together with nearby universities, promoting technology products to the society and helps make life more convenient.

***Figure 36*** *Technological innovation products exhibition*

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# X. Appendices

## A. Operational Checklist

**Personal Protective Equipment**
- ☐ Wear protective equipment
- ☐ Area cleared and tether straightened(no tripping hazards)

**Pre-launch(air pump)**
- ☐ Air pump on deck connected and secured
- ☐ Gas circuit cleared
- ☐ Air pump connected and secured to pneumatic equipment
- ☐ No damage on pneumatic equipment

**Pre-launch(machinery safety)**
- ☐ Visual inspection for loose connections and abraded blades
- ☐ Buoyancy devices secured and fixed
- ☐ Thrusters secured
- ☐ Sheaths on thrusters secured
- ☐ Manipulators secured and fixed
- ☐ Transmission parts on manipulators secured

**Pre-launch(circuit)**
- ☐ Power switches, circuit breakers and emergency switches verified
- ☐ Tether connected and secured to ROV
- ☐ Inspection for tangles within tether
- ☐ Electronics housing securely sealed
- ☐ No damage on O-ring
- ☐ Wires securely connected and no damage
- ☐ Watertightness of connections outside
- ☐ Watertightness of wires connected to thrusters
- ☐ Visual inspection for debris on thrusters

**Power-up(communication)**
- ☐ Networks on deck securely connected
- ☐ Networks in the electronics housing securely connected

**Power-up(thrusters)**
- ☐ Thrusters well functioned
  5A for each thrusters
- ☐ Inspection for reversal of thrusters

**Power-up(manipulators)**
- ☐ Manipulators normally operated
  3A for each stepping motor
- ☐ Inspection for stripped screw

**Power-up(data detection)**
- ☐ Electrical current within 2A when ROV is powered on
- ☐ Electrical current within 10A when thrusters and manipulators are activated
- ☐ Electrical current within 15A when all thrusters and manipulators are drawn under full load
- ☐ Indicator lights on

**In water(leak detection)**
- ☐ Detection of pressure in electronics housing(similar to standard atmospheric pressure)
- ☐ Normal humidity at sealing points
- ☐ In water(communication)
- ☐ Stable data transmission
- ☐ High image definition on cameras
- ☐ In water(thrusters)
- ☐ Inspection for spray generated by thrusters
- ☐ Inspection for reversal of thrusters

**In water(manipulators)**
- ☐ Manipulators normally operated
- ☐ Inspection for loose clampings of manipulators

**ROV Retrieval(communication)**
- ☐ Stable data transmission
- ☐ Inspection for damage on wires
- ☐ Dry and caps of electronics housing and un-
- ☐ plugging connectors
- ☐ Wires well coiled

**ROV Retrieval(thrusters)**
- ☐ Inspection for abraded blades
- ☐ Networks on deck securely connected
- ☐ Thrusters dismantled and sorted

**ROV Retrieval(manipulators)**
- ☐ Stepping motors well connected
- ☐ Inspection for damaged transmission parts
- ☐ Manipulators dismantled and sorted

**ROV Retrieval(data detection)**
- ☐ Inspection for incorrect feedback data
- ☐ Energy storage element normally discharged
- ☐ Circuit dismantled and sorted

**Transportation**
- ☐ ROV dismantled
- ☐ Dry components
- ☐ Packaging

## B. Budget

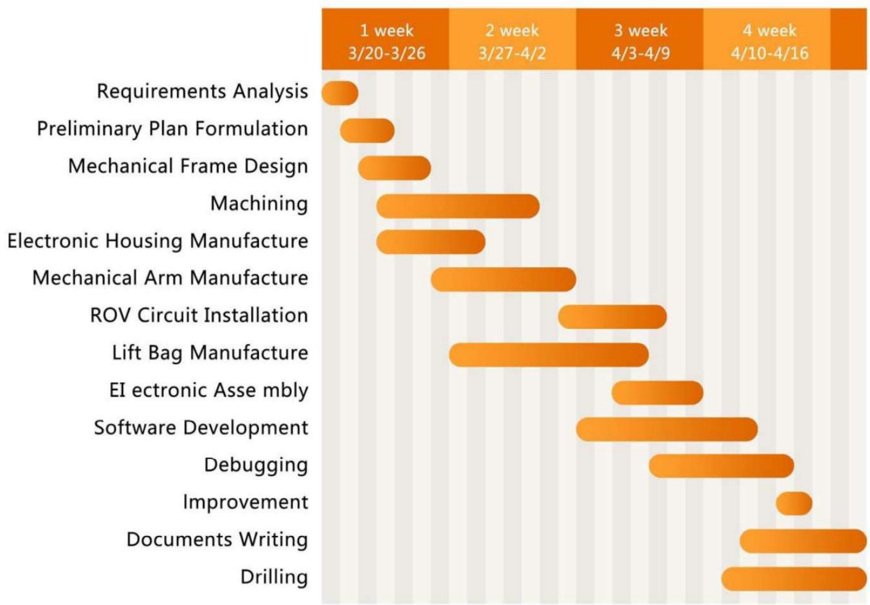
| Project Income | | Blue Whale II Manufacturing | | Travel Expenses | |
|---|---|---|---|---|---|
| Item | Amount(¥) | Mechanical&Chemical Materials | 20000¥ | Train | 100000¥ |
| From the Institute | 150000¥ | Electronic Devices | 20000¥ | Taxi | 2000¥ |
| From corporations | 30000¥ | Machining | 5000¥ | Hotel | 15000¥ |
| Crowdfunding | 5000¥ | Electronic Processing | 5000¥ | Board | 3000¥ |
| Total(¥) | 185000¥ | Total(¥) | 50000¥ | Total(¥) | 120000¥ |
| Project Income: 185000¥ | | | | | |
| Cost Estimate: 170000¥ | | | | | |

## C. Cost Image Processing Flowchart

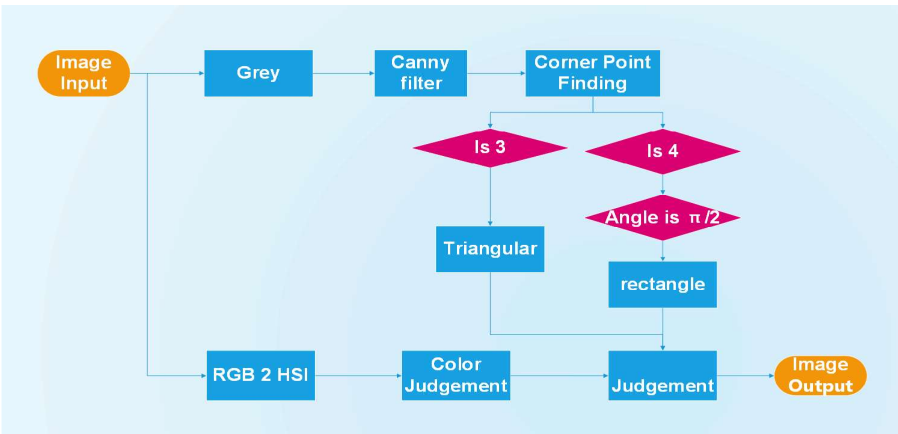
| Category | Item | Amount(¥) |
|---|---|---|
| Electronic Devices | | |
| Purchased | Thrusters | 12800 |
| Purchased | ESC | 624 |
| Purchased | 24V DC Voltage Regulator | 150 |
| Purchased | 12V DC Voltage Regulator | 600 |
| Purchased | 5V DC Voltage Regulator | 100 |
| Purchased | 3.3V DC Voltage Regulator | 50 |
| Purchased | Router | 200 |
| Purchased | Interchanger | 200 |
| Re-used | STM32 | 50 |
| Purchased | Raspberry Pi | 220 |
| Purchased | WIFI Module | 30 |
| Purchased | Stepping Motor | 320 |
| Purchased | Digital Cameras | 285 |
| Purchased | Analog Cameras | 272 |
| Purchased | Pressure Sensor | 380 |
| Purchased | IMU | 75 |
| Purchased | Temperature and Humidity Sensor | 40 |
| Purchased | Joystick | 180 |
| Purchased | LEDs | 250 |
| Total(¥) | | 16826 |

| Category | Item | Amount(¥) |
|---|---|---|
| Electronic Processing | | |
| Purchased | Printed Circuit Board | 2000 |
| Re-used | Plugs & Sockets | 360 |
| Re-used | Electromagnetic Shielding Wire | 450 |
| Purchased | Cable | 200 |
| Total(¥) | | 3010 |
| Mechanical&Chemical Materials | | |
| Purchased | Buoyancy | 5000 |
| Purchased | Propellers | 660 |
| Purchased | Electronic Housing | 1880 |
| Purchased | 1515 Aluminum Alloy | 500 |
| Purchased | O-ring | 100 |
| Purchased | Epoxy Resin | 1810 |
| Purchased | PVC Tube | 200 |
| Total(¥) | | 10150 |
| Machining&Chemical Processing | | |
| Purchased | 3D Printing | 3750 |
| Purchased | CNC Milling | 2139 |
| Purchased | Laser Cutting | 4400 |
| Total(¥) | | 10289 |
| Total(¥):40275 | | |

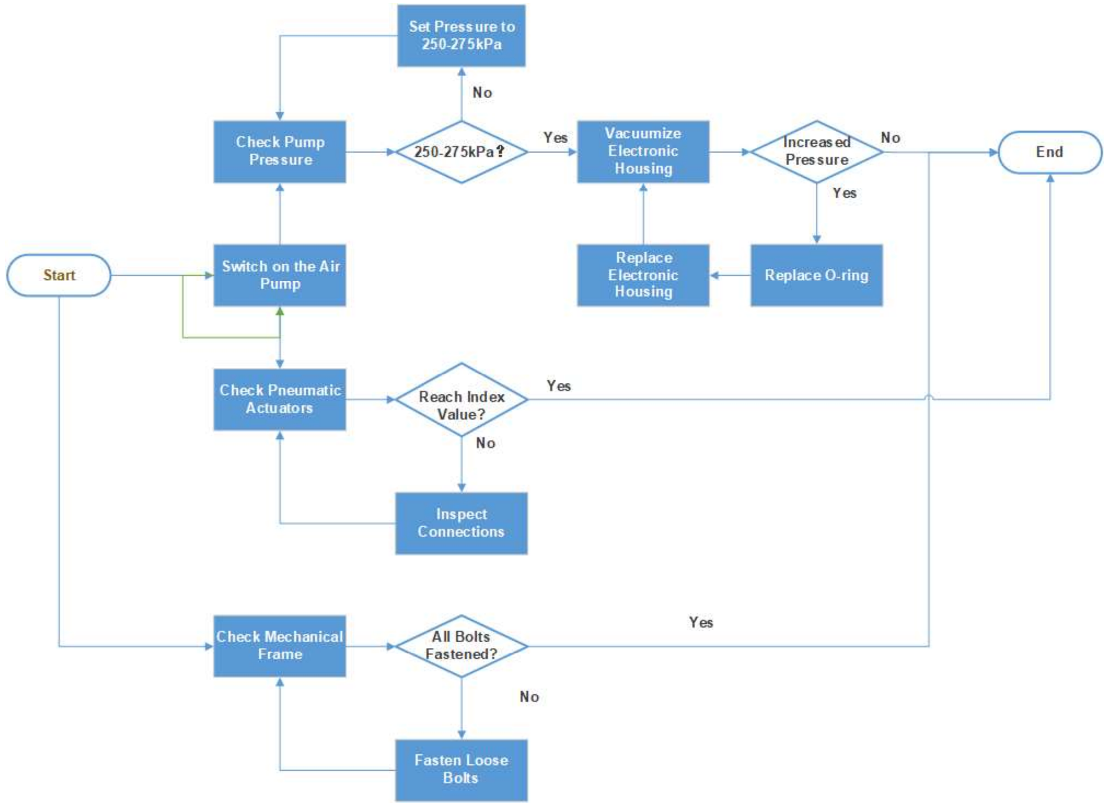
## D. Gantt Chart



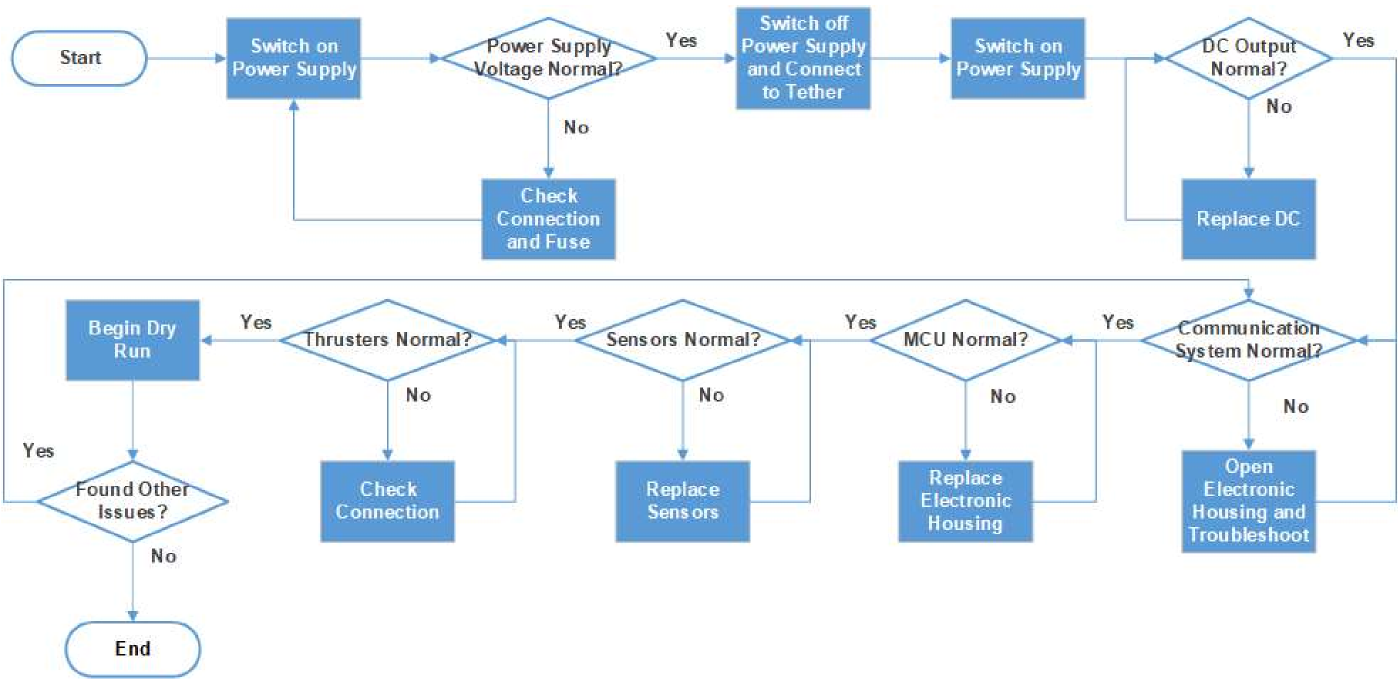

## E. Image Processing Flowchart



## F. Mechanical maintenance flow chart




## G. Electronic maintenance flow chart



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