The Phoenix

Technical Documentation
Macau Pui Ching Middle School
Macau SAR, China

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I. Abstract

Nirvana is a product designed by the Phoenix (Fig. 1), a team of 5 passionate students from the Macau Pui Ching Middle School, after approximately 2,583 hours of hard work, at a total production cost of USD2,685, on the request of 2019 MATE ROV Competition to support staff of the Eastman at Eastern Tennessee to carry out inspection as well as repair the dam, maintain healthy waterways, replenish the ecological system, and conduct cannon identification and retrieval.

Fig. 1 Team photo of the Phoenix

Nirvana (Fig. 2) has a size of 484mm x 484mm x 270mm and is 13kg in weight, which meets the size and weight restrictions. Its flattened octagonal prism design contributes to better stability and less drag while a 6-thruster vectored configuration maximizes maneuverability. Most of the structural components and tools are self-made which result in a relatively low cost and enables customization for different missions. Nirvana's flattened octagonal prism design with a 3D printed shell, besides giving an amazing appearance, also provides sufficient space in the center to hold a watertight enclosure with the electronic system in it and the placement of the tools under the enclosure. Nirvana is equipped with five cameras for a comprehensive view of the underwater situation and multiple tools such as grout container, tire collector, temperature sensor and metal detector to carry out required missions.

Fig. 2 Photo of complete vehicle

II. Design Rationale

1. Design Philosophy

Nirvana is a refined version of Eugene, our ROV of the previous year, with the following essential improvements. Firstly, A hollow homemade 3D printed shell is added to decrease water resistance, and a rigid connection with the use of mortise joints between components results in a more stabilized frame (Fig 3). Secondly, ArduSub is used as the control system of Nirvana with

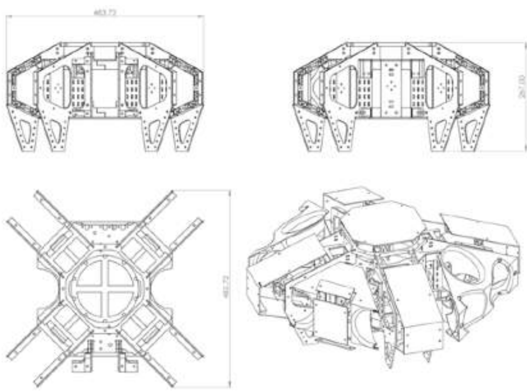


Fig. 3 Engineering Drawing of Nirvana

QGroundControl as its base station software. Thirdly, Raspberry Pi 3 and Pixhawk are the two main hardware used in Nirvana. Compared with the Arduino Uno in our previous ROVs, this control system is comparatively more stable and is adjustable with ease in accordance with the missions.

All these reforms favor a smaller size, higher stability and user-friendly model, affirming the philosophies of high mobility, compatibility and surveillance ability as well as of easy transportation.

2. Material choice

Our initial choice of manufacturing technique was 3D print. Instead of ABS, which was used in our previous ROVs, PLA is chosen as it is more environmentally friendly, in addition to its low cost and ease of use. However, using just 3D printed components are too fragile, which a lightweight and hard material is considered. Stainless steel was used in our previous ROVs, yet it is heavy and hard to be managed in our workshop. Research was done and our conclusion is that 6061 aluminum plates are the ideal material for building a stable and hard frame. Aluminum plate can be easily managed and handled in the CNC machine in our workshop as it is malleable (Fig. 4).

	Panels		3D printed material	
Material	Aluminum (6061)	Stainless steel	PLA	ABS
Density (g/cm³)	2.7	8.05	1.25	1.07
Ease of manufacture	Lightweight, durable	Heavy, hard to be managed in workshop	Malleable, easy to print	Produce toxic fumes when heated
Choice	✓	✗	✓	✗

Fig. 4 Choice of material

3. Frame

With the inspiration of a UFO, Nirvana has a flattened octagonal prism design. At first, four 3D printed solid blocks were produced to lock the watertight enclosure in an upright position at the center of the frame. Yet, the solid blocks were later replaced by hollow ones to comply with the weight restriction. 3mm aluminum 6061 plates are placed at the two ends of this frame and joined to the 3D printed blocks with mortise joints (Fig. 5) and screws. As tools for specific missions will be put under the watertight enclosure, eight additional legs are mounted at the sides of aluminum boards to provide space for the placement of the tools and other devices to enable the frame to stand in a balanced vertical position. Each pitch-row on all aluminum boards has the same spacing with one another, which provides standardization and facilitates the adjustment of the location of the components. Finally, a shell composed of seven homemade 3D printed parts in some geometrical shapes is designed to cover the frame to reduce water resistance and project Nirvana's outstanding appearance (Fig. 6).

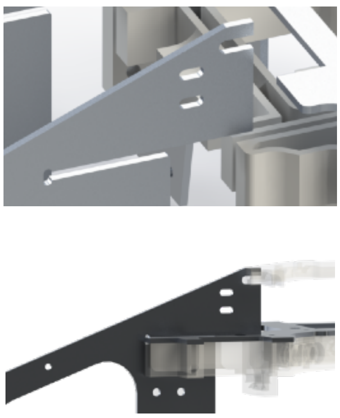


Fig. 5 Mortise joint

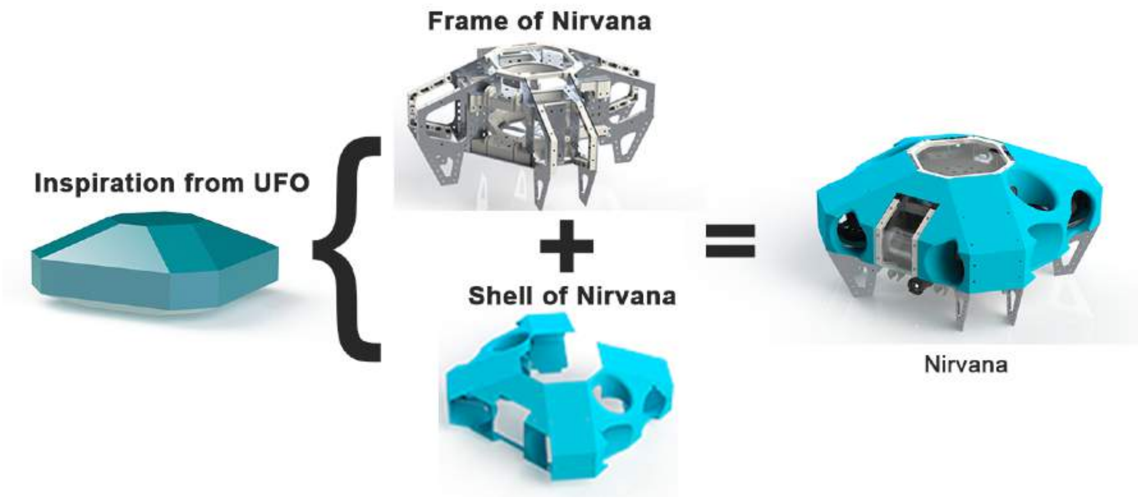


Fig. 6 Process from inspiration to final product

4. Waterproof

Housing the electronic components in a watertight enclosure enables the reuse of components and is more convenient for maintenance, compared with epoxying the electronic components. Furthermore, it is more economic and more reliable to buy a commercially-available watertight enclosure than making a customized enclosure on our own. Yet to fit our actual use, a 6” watertight enclosure is more than enough but this size is not available in the market. Separated parts of the enclosure are bought, such as the customized size acrylic cylinder, end caps and flanges, for composing our desired size enclosure.

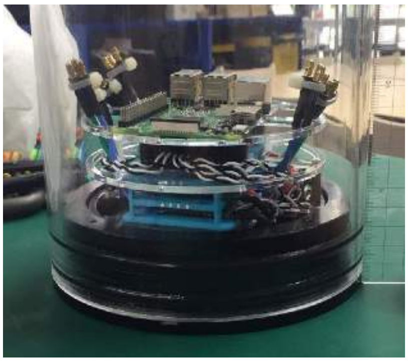


Fig. 7 Watertight Enclosure

The semi-customised enclosure (Fig. 7) consists of an acrylic tube, two end caps, and two flanges. The cylindrical shape enclosure is placed in an upright position which favors to house more efficiently the electronics when compared to a horizontal orientation. The volume of the enclosure has been greatly reduced so that the vehicle can have a smaller design to fit the size restriction. The transparent acrylic tube with an outside diameter of 160mm, inside diameter of 152mm, a thickness of 4mm, as well as a height of 120mm, enables the pilot to observe the status of the ROV through the LED signal light from the underwater control system.

5. Buoyancy

In order to manipulate our ROV smoothly, the flotation of Nirvana has been determined using the Archimedes principle before manufacturing:

$F_{buoyant} = \rho Vg = 1000\ kgm^{-3} \times 9.7\times10^{-3}m^3 \times 10\ Nkg^{-1} = 97N$

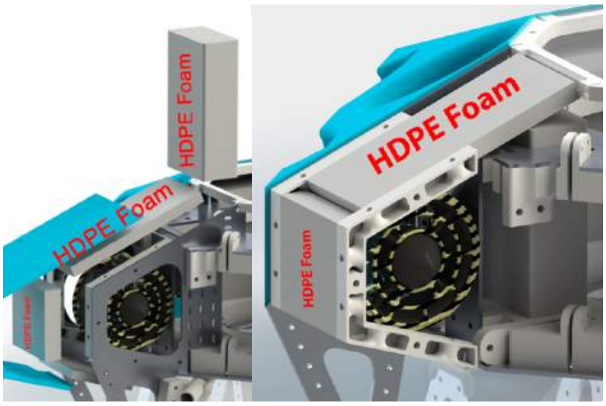


Fig.8 Buoyancy

Float boards (Fig. 8) can easily be installed on top of the flattened shell to adjust buoyancy. High-density Polyurethane Foam (HDPE) is chosen due to its high density and its resistance to high water pressure.

Moreover, based on the flotation of Nirvana, $4\times10^{-3}m^3$ of floatation is still need to be added to meet the upthrust requirement Thus, additional floats are mounted on the shell to balance the movement of Nirvana.

6. Propulsion

In order to complete tasks efficiently, the composition of thrusters plays an important role. Six thrusters are used in Nirvana, four for horizontal movements and two for vertical movements (Fig. 9). The horizontal thrusters are placed at an angle of 45 degrees to provide the largest thrust for Nirvana to move in high efficiency. Moreover, to follow the transect line, Nirvana has to transfer from one side of the board to the other, and placing the thrusters at an angle of 45 degrees enables Nirvana to move left and right without spinning around.

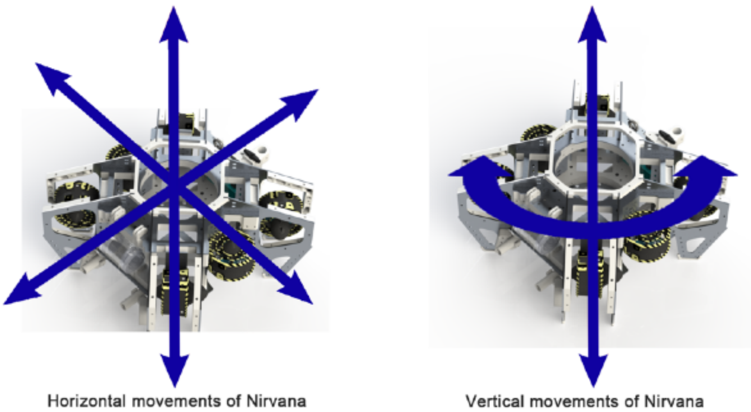


Fig. 9 Propulsion system

The skills required to build thrusters with quality competitive to commercial products exceed our capability and thus we opted to purchase the thrusters. Compared with similar commercial products, BlueRobotics T-200 thrusters have a better stability and compact in size. Moreover, BlueRobotics T-200 thrusters require lower power to operate. Provided that same currents are given, T200 obviously gives a larger thrust than T100 which results in a higher speed. Thus, BlueRobotics T-200 thrusters are selected for our propulsion system.

7. Tether

Nirvana's tether consists of two power cables and two ethernet cables. They are wrapped in a cable braided sleeve for protection (Fig. 10) and is about 15 meters long to safeguard free movement. 10 AWG power cables are chosen to ensure that a current of 25A is able to convey to the ROV, as insufficient amount of current will lead to constant reset which severely affects Nirvana's performance. One of the Ethernet cables is the communication bridge between the on-shore computer and the Raspberry Pi of the underwater control system, while the other ethernet cable is a signal channel between the underwater control system and the onshore operating system. They are used for data and video signal transfer. Unstable camera connection was spotted during operation, hence the original ethernet cable connecting the underwater control system and the onshore operating system is finally replaced by a BlueRobotics Fathom tether which has better quality and transmission speed.

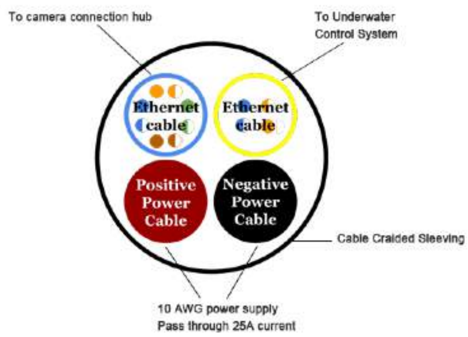


Fig. 10 Inside view of tether

All of the connectors between the tether and the onshore control box are separable so that the tether can be detached from the control box. The detached tether is then managed with a movable wire spool for easy transportation. For a second protection to the tether, a strain relief is added so that any eventual tension will be transferred to the mainframe (Fig. 11).


Fig. 11 Tether management

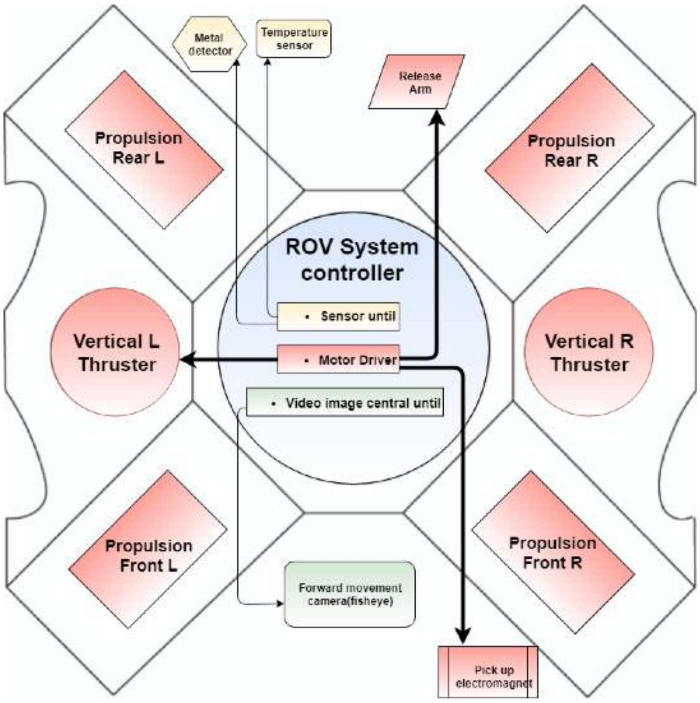


Fig. 12 Signal Diagram of Nirvana

8. SID

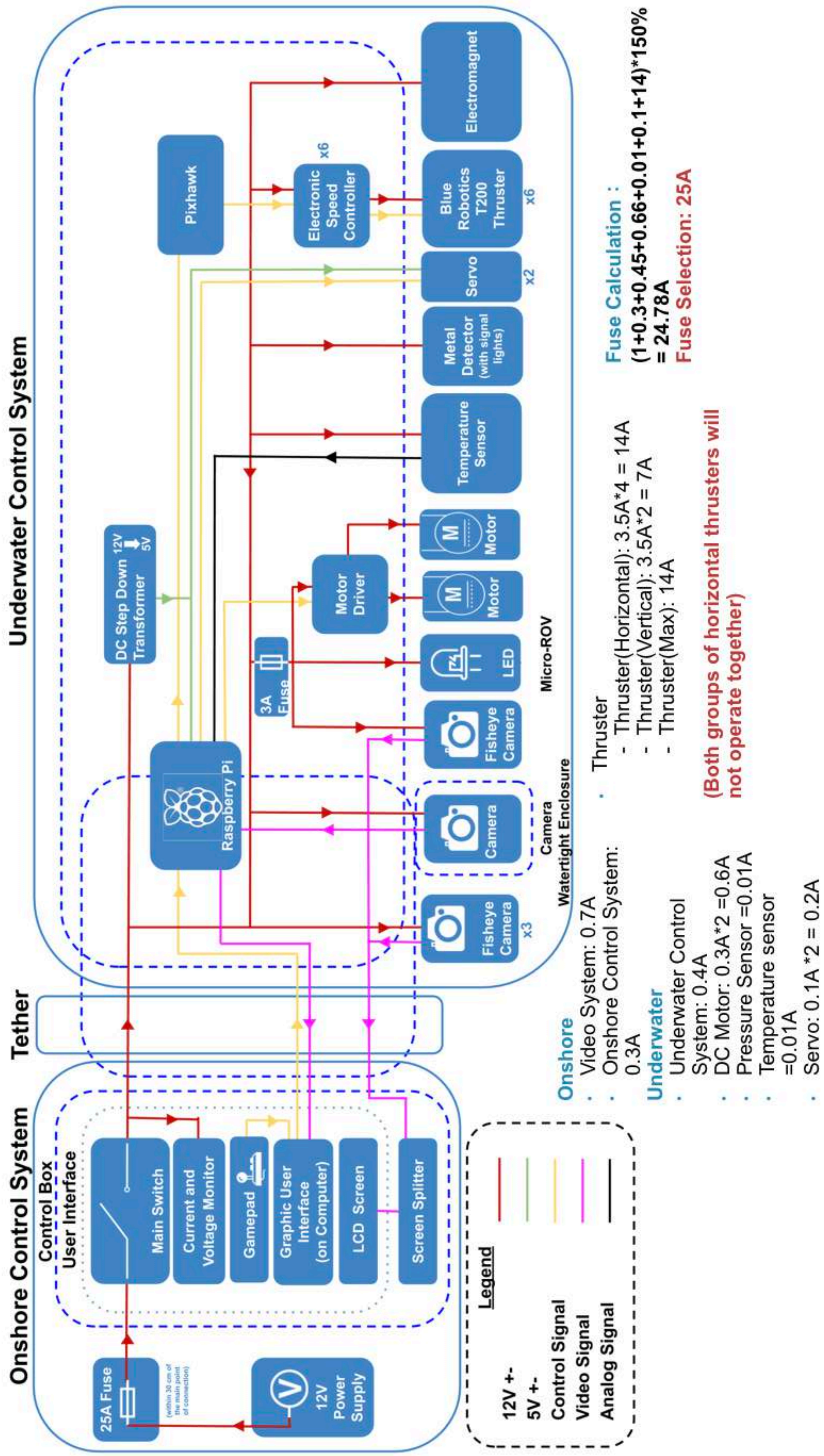


Fig. 13 SID of Nirvana

III. System Architecture

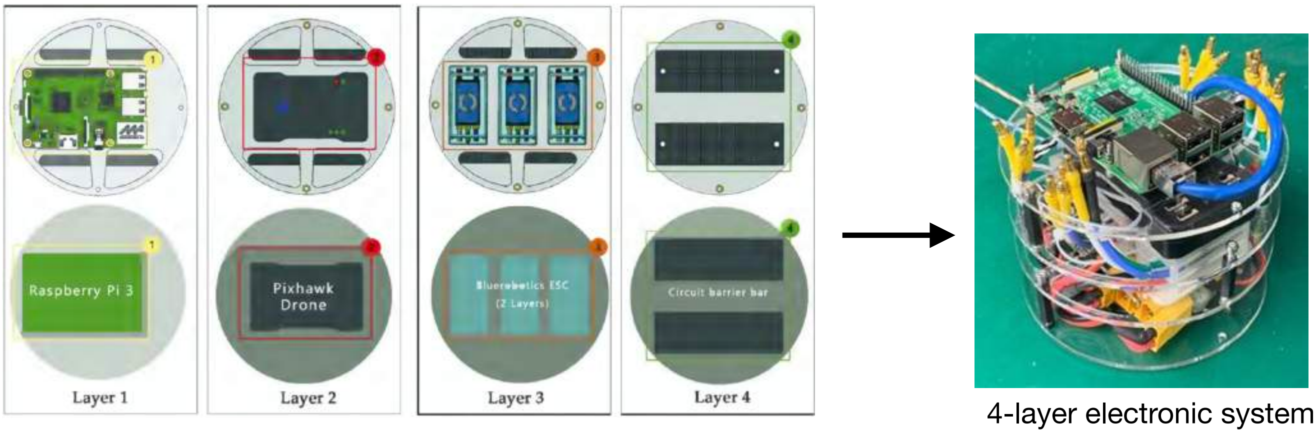
1. Operating System

The control box of Nirvana (Fig. 14) is designed with a voltage monitor. It consists of a 15.6” monitor mounted on the cover, on which signals from four cameras are shown so that the pilot can take them for reference for a better performance of the different tasks and missions. The whole electrical circuitry is positioned at the bottom of the control box. A screen splitter is used for amplifying the camera signals while ensuring their quality. A gamepad is used for the pilot to manipulate Nirvana in a handy way.

Fig. 14 Pilot operating Nirvana

2. Underwater Electronics System

The underwater system (Fig. 15) has been modified in multiple aspects such as its size, the wiring design and the inner components. The size and the weight of the underwater system has been reduced compared to last year’s electronics system. The method of transmitting video signals through optical fiber is no longer used due to its fragility and an external video signal connection hub is built to substitute it. Instead of using a two-layer design which was used in the previous year, four layers are found to be more suitable for vertical position. The layout of the system is precisely planned so that the wires will not be bundled up.



4-layer electronic system

Fig.15 Electronic system

Compared to last year’s underwater electronics system which used Arduino Uno as the core control board, Nirvana opts to use ArduSub as the main source of its control system and QgroundControl as the base station software. Raspberry Pi and Pixhawk are the two main hardwares for communication of network in Nirvana. This kind of composition of the control system functions better and provides higher stability than the control system in our previous ROVs which used an Arduino board that requires programming. Raspberry Pi, the network in the communication protocol, receives the control signals from the base station and and through the real-time data streaming process conveys the images back to the base station, enhancing the efficiency in transmission of control signals. On the other hand, Pixhawk is connected to Raspberry Pi through USB port. It serves as a commander controlling the steering and speed of the Electronic Speed Controllers (ESCs), as well as receiving data from the I^2C sensors and conveying them back to Raspberry Pi.

3. Camera system

The camera system comprises one low light USB camera and four fisheye cameras (Fig. 16). The USB camera at the front of Nirvana and together with a servo are placed in a mini-water enclosure and with the help of the servo, the USB camera can adjust its position and enables a view of tilted angle, which is ideal for the mission of image recognition.

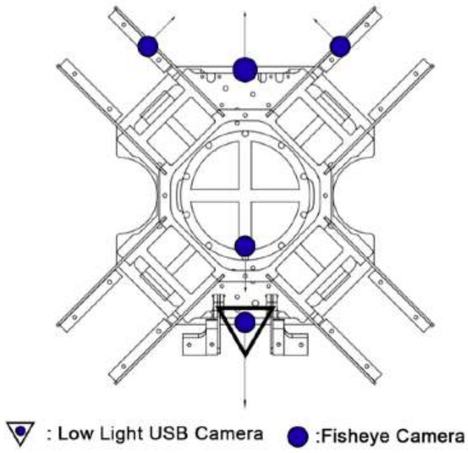


Fig. 16 Position of cameras

On the other hand, 4 waterproofed fisheye cameras are used for monitoring the environment around Nirvana. All 4 cameras are connected to the external camera connection hub (Fig.17) located at the back of Nirvana, where all camera signals are gathered and transmitted through the ethernet cable to the control box. Finally, captured video will be shown on the monitor on the control box onshore.

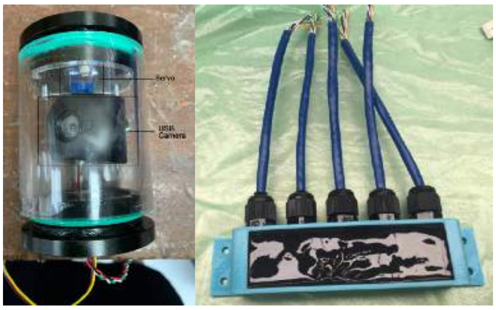


Fig. 17 USB camera and camera connection hub

4. GUI

The GUI of Nirvana (Fig. 18) has several windows. The main window is the QGroundControl which is used to show the sensor data together with the USB camera screen capture. The QGroundControl is an open source featured ROV solution which can be easily used by pilots to control the ROV. The QGroundControl is chosen because it can provide a clear layout of different data, such as gyro and servo

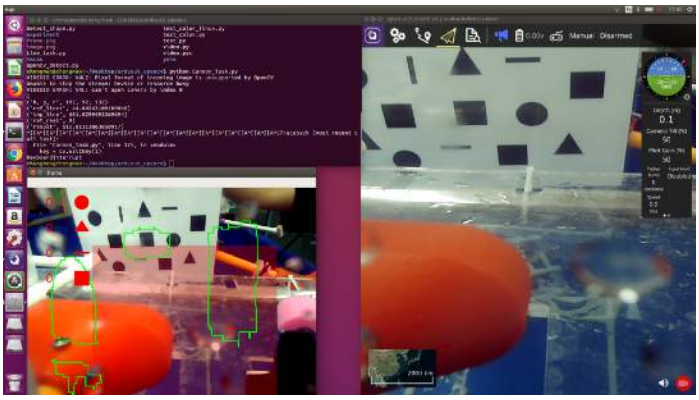


Fig. 18 Graphic User Interface

tilt percentage. It also allows our ROV to use PID control to smoothen its movement. The second window of the GUI is the Linux terminal, which runs the image recognition system and gives an accurate result of various counting and measurement.

5. Mission Specifics

5.1 3D printed holder

The 3D printed holder (Fig. 19) is specifically designed for mounting the electromagnet and the multi-purpose hook on Nirvana. The holder can lock the ½ inch PVC pipes, which are mounted at the back of both the electromagnet and the hook, on one of the legs of Nirvana.

Fig. 19 3D printed holder

5.2 Interchangeable Mechanism (IM)

The IM (Fig. 20) is an innovative mechanism designed by us, which is applicable to all vertically placed tools with a ½ inch PVC pipe at the rear, such as grout container and the tire collector. The MI is comprised of two 3D printed parts and a ball lock pin. To disassemble a tool, the pilot only needs to press the button on the ball lock pin and the tool can be released.

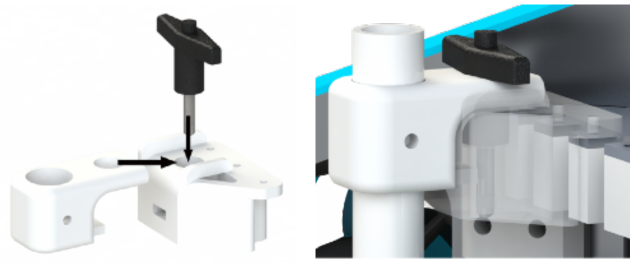


Fig. 20 Interchangable Mechanism

5.3 Multi-purpose hook

The multi-purpose hook (Fig. 21) is designed for gripping ropes. U-bolts that cannot be lifted by the electromagnet can also be gripped by the hook. Aluminum bars are chosen as the main material of the hook due to its durability. The hook is mounted on Nirvana through the 3D printed holder.

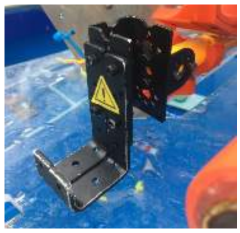


Fig. 21 Multi-

5.4 Electromagnet

The electromagnet (Fig. 22) is used to grip and release magnetic material, like the mission of gripping U-bolts. Two 90N electromagnets are chosen, installed into a 3D printed shell with a tiny built-in hook, to lift the cannon which has the maximum weight of 50 N. With the 3D printed holder, the electromagnet will be mounted on Nirvana.

Fig. 22 Electromagnet

5.5 Lift capacity

As indicated by the technical specification provided by the BlueRobotics, the maximum lift force under 12V for two T200 thrusters without exceeding the current restriction of 25A is 161 N. With the deduction of 50N, which is the maximum weight of the cannon provided by MATE, Nirvana has a lift capacity of 111 N (Fig. 23). With this lifting capacity, the ROV itself can already lift the cannon, which no lift bags are needed. As such, no additional air tubes are needed to inflate the lift bags.

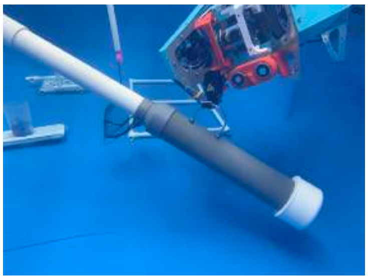


Fig 23 Nirvana lifting the cannon

5.6 Temperature sensor and Metal detector (TS-MD)

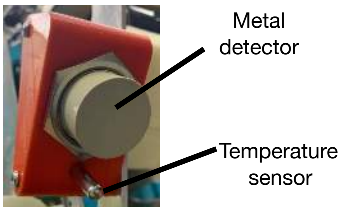


Fig.24 TS-MD

Data of different elements like water temperature, metal substance and toxins are to be collected in order to keep track of the situation in the deep sea and used for reference for maintaining healthy waterways. Hence, a TS-MD is designed. Considering the disposition of the cameras, the sensor and the detector are put together in a 3D printed shell (Fig. 24) and only one single camera is used to monitor them. Measured and collected data are transmitted by the Raspberry Pi to the onshore computer.

5.7 Grouts and trout fries container

Composed of a cup, a 3D printed holder and an acrylic lid with a servo, the container (Fig. 25) is the perfect tool to transfer grouts and trout fries from onshore to underwater. The container is attached to our ROV through the holder and the servo enables the pilot to control the the water drain lid. When our ROV approaches the destination, the pilot switches on the servo to swing open the lid and the grouts and trout fries will drop into the target area accurately.

Fig. 25 Grouts and trout fries container

5.8 Tire collector

The tire collector (Fig. 26) is bound with a rubber band which provides certain elasticity for the collector to split open slightly and grip the tire firmly. It is a 3D printed component with inclined planes at the bottom and the inclination is carefully calculated which helps the collector slide easily into the tire. A ½ inch PVC pipe is built at the rear of the collector so that the interchangeable mechanism can be applicable to it.

Fig. 26 Tire collector

5.9 Micro ROV

A Micro ROV (Fig. 27) is made for the mission of the drain pipe inspection. It consists of a pump, a fisheye camera, a magnet and a LED strip and a 3-Amp fuse is added for overcurrent protection. The semi-oval shell of the Micro-ROV with pulleys on the roof enables the micro ROV to swim through the drain pipe smoothly. The LED strip provides light inside the dark drain pipe, and images of dam failures can be captured by the fisheye camera and are transferred through the ethernet cable to the onshore control system. The magnet in the front of the ROV is used for docking.

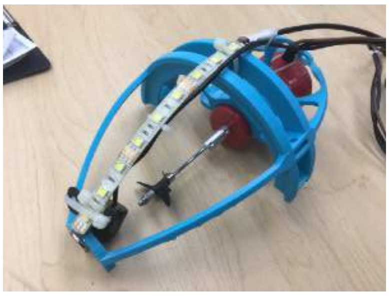


Fig. 27 Micro-ROV

5.10 Image Recognition System

To deal with the mission of benthic species identification (Fig. 28), an image recognition system is set up with the use of Python and OpenCV.

As the black figures are shown on a white-board, the USB camera at the front of Nirvana captures the image of the white board. Then the location of all the black figures is found through image thresholding processing. To do so, RGB values are converted into HSV format which allows the identification of the two different colors according to their brightness values V. Low values V stand for black while high values V stand for white.

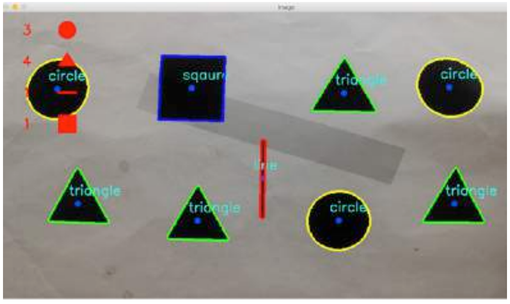


Fig. 28 Benthic species identification

For the detection of the shapes of these black figures, as there may be different kinds of noise jamming which hinder the accuracy of the detection, findcontours(), a noise reduction function (erode and dilate) in the software is applied to make the black areas more recognizable. Here the shape of the black figures is analyzed one by one. With the approxPolyDP() in OpenCV, the number of angles of each figure is detected: 3 angles for triangle, 4 angles for square or rectangle, and >7 angles for circle. When the identification of the triangles and circles is done, the 4-angled figures are squares or rectangles are then identificated. With the calculation of the proportion value between the width and the length of the figure, it is easy to determine its shape. After all these comparisons and calculations, results of detected signals will be sent through Raspberry Pi directly to our computer monitor (Fig. 29).

The image recognition system is also used for identifying cracks on the transect line as well as for volume calculation of the cannon. When our ROV approaches the cracks, pictures are captured and transferred through Raspberry Pi to our computer monitor.

Based on these pictures, the appropriate datum lines are analyzed and the proportion value of the cracks on these datum lines are analysed and hence, with the help of the proportion of the pictures with the real objects, the longest crack can be identified and its actual length can be calculated.

As for the volume calculation of the cannon, with the same theory used in the crack measurement, the diameters of the three circles at the two ends of the cannon and the length of the cannon are measured. The volume of the cannon is calculated immediately (Fig. 30) with these data using Microsoft Excel.

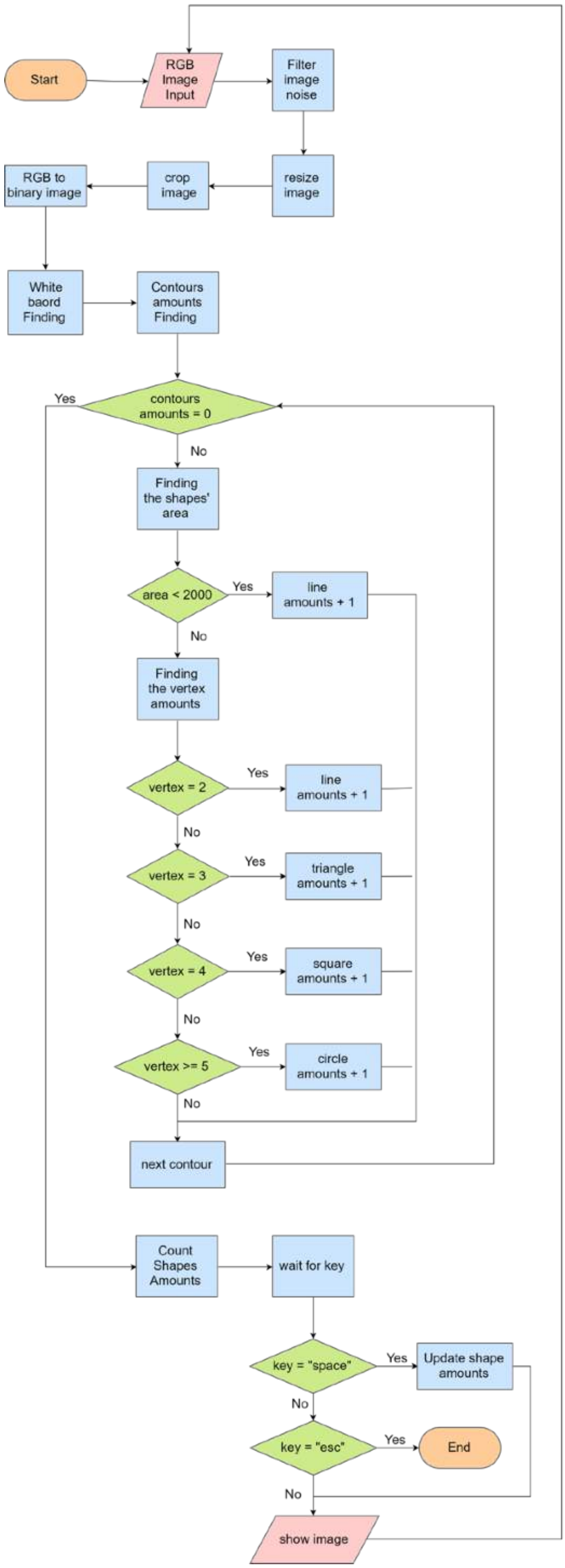


Fig. 29 Benthic species identification flowchart

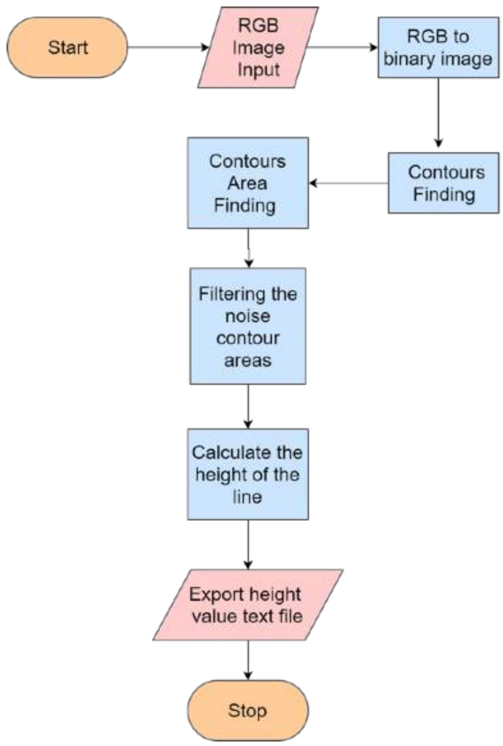


Fig. 30 Identifying the cracks flowchart

IV. Finance

A budget of the project was made based on the expenses of our last year ROV, once the decision on participation in the competition came out. According to previous experience, the only source of income comes from our school, the Macau Pui Ching Middle School. With limited income, each of the expenditure must be justified and should stick to the budgeted cost. In each purchase, price comparison is done to choose the most suitable product at the lowest cost. On the other hand, to keep up with our budget and minimize our project cost, an evaluation of the pros and cons of the need to purchase, build or reuse is made for each component for making decision.

1. New VS Reused Components

Again to consider buying or reusing certain components, two factors are taken into consideration: our budget and the compatibility of the component. The thrusters still show good performance and reusing them can greatly alleviate our budget pressure. On the other hand, besides reducing the production cost, the gamepad and the monitor are reused since our pilot is familiar with them and time can be saved for adaption.

2. In-House Built VS Commercial Components

Our workshop, Fablab Pui Ching — Macao , is a well-developed laboratory for us to manufacture our ROV. In such good environment, teammates have the opportunity to use different machines. The operation of machines are included in our school curriculum, so all team members have basic knowledge of how to operate machines safely. Teammates are trained to use machines such as the 3D printers and the CNC machine (Fig. 31) under strict safety protocols, hence many of the components are managed in our workshop.

Fig. 31 Teammates using the CNC machine

For example the frame of Nirvana, consisting of aluminum plates and 3D printed part, is manufactured in our workshop. The aluminum plates are cut out in the CNC machine while the 3D printed parts are manufactured in the 3D printers in the lab. These components are customized and specifically designed to fit the tasks, and no similar products are available on the market. The 3D printed shell of Nirvana is assembled from seven parts (Fig. 32) while compared to highly-cost factory-made 3D print components, 3D printing these components in our workshop can alleviate our budget pressure.

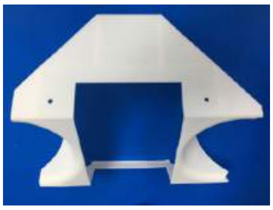


Fig. 32 Part of shell of Nirvana

In contrast, thrusters were bought instead of self-built, as it is costly, time consuming and most of all, producing a thruster with equal quality as the commercial ones is far from our capability.

3. Budget

Budget				Reporting Period
School Name:	Macau Pui Ching Middle School			From: 08/2018
Instructor:	Thomas Lao, Chongman Leong, Derek Leong			To: 06/2019
Income				
Source				Amount (USD)
Macau Pui Ching Middle School Grant				$ 19,115.00
Expenses				
Category	Type	Description/ Examples	Projected Cost (USD)	Budgeted Value (USD)
Hardware	Donation	Aluminium sheet, PLA filament, Screws	$ 140.00	$ 0.00
Electronics	Purchased	Blue Robotics Watertight Enclosure (6″ Series)	$ 300.00	$ 300.00
Electronics	Re-used	Blue Robotics T200 Thrusters	$ 1,015.00	$ 0.00
Electronics	Re-used	Logitech F310 Gamepad	$ 25.00	$ 0.00
Electronics	Purchased	Blue Robotics Fathom ROV Tether	$ 60.00	$ 60.00
Electronics	Re-used	Control box, Cameras, Monitor	$ 220.00	$ 0.00
Public Relatio	Re-used	Marketing material, Props	$ 50.00	$ 0.00
Travel	Purchased	Transportation, Accommodation fees to internati	$ 11,500.00	$ 11,500.00
			Total Income:	$ 19,115.00
			Total Expenses:	$ 13,310.00
			Total Expenses-Re-use/Donations:	$ 11,860.00
			Total Fundraising Needed:	$ 7,255.00

Fig. 33 Budget

4. Project costing

Project Costing						Reporting Period	
School Name:			Pui Ching Middle School			From: 08/2018	
Instructor:			Thomas Lao, Chongman Leong, Derek Leong			To: 06/2019	
Funds							
Date	Type	Category	Expense	Description	Source/Notes	Amount	Running Balance
10/9/2018	Cash Donated	Funds		Funds from school	Used for vehicle construction	$ 18,560.00	$ 18,560.00
13/9/2018	Purchased	Hardware	Watertight enclosure	Blue Robotics Watertight Enclosure (6″ Series)	For underwater control system	$ (300.00)	$ 18,260.00
13/9/2018	Purchased	Electronics	ROV electronics package	Blue Robotics Standard ROV Electronics Package	For underwater control system	$ (315.00)	$ 17,945.00
15/9/2018	Purchased	Electronics	Raspberry Pi	Raspberry Pi 3 B	For underwater control system	$ (30.00)	$ 17,915.00
15/9/2018	Purchased	Electronics	ESCs	Blue Robotics Basic ESCs	For T200 thrusters	$ (150.00)	$ 17,765.00
15/9/2018	Purchased	Electronics	Fuse		Used for underwater control system	$ (5.00)	$ 17,760.00
22/9/2018	Re-used	Electronics	Thrusters	Blue Robotics T200 Thrusters	For proportion system	$ (1,015.00)	$ 17,760.00
3/10/2018	Parts Donated	Hardware	PLA filaments, Screws, Aluminum sheet	Parts donated by school	For frame of ROV	$ (55.00)	$ 17,760.00
27/10/2018	Purchased	Electronics	LED, Sensors, Network cable		For video system	$ (330.00)	$ 17,430.00
27/10/2018	Purchased	Electronics	Tether cable	Blue Robotics Fathom ROV Tether	For video system	$ (60.00)	$ 17,370.00
31/10/2018	Re-used	Electronics	Cameras, Control box, Monitor		For video system	$ (220.00)	$ 17,370.00
2/11/2018	Re-used	Electronics	Gamepad	Logitech F310 Gamepad	For video system	$ (25.00)	$ 17,370.00
5/12/2018	Parts Donated	Hardware	PLA filaments, Electromagnets	Parts donated by school	For tools and Mini-ROV	$ (90.00)	$ 17,370.00
17/1/2019	Parts Donated	Electronics	Acrylic boards, Anderson Ports, Banana plugs	Parts donated by school	For onshore control system	$ (90.00)	$ 17,370.00
20/3/2019	Re-used	Public Relations	Marketing material, documents		For documentation submission	$ (50.00)	$ 17,370.00
10/5/2019	Purchased	Travel	Travel fee to international competition	Airfare, accommodation, general spending	For international competition	$ (11,500.00)	$ 5,870.00
12/5/2019	Cash Donated	Funds		Funds from school	Used for international competition	$ 4,500.00	$ 10,370.00
						Total Raised	$ 23,060.00
						Total Spent	$ (12,690.00)
						Final Balance	$ 10,370.00

Fig. 34 Project Costing

V. Safety

1. Company Safety Philosophy

Nothing is more important than the teammates' health and safety. Hence, refresher lessons are held regularly to arouse teammates' awareness of hazards and to raise their concerns about safety. Besides using protection gears and PPE, vigilance is the key to overall safety. Safety checklists, which have been made according to the potential hazards determined through the JSA, must be completed during the construction of the vehicle as well as in every pilot training and all ROV testings (Fig. 35).

Fig. 35 Teammates using safety checklist

2. Safety in Workshop

A guidebook about safety in workshop has been compiled, telling the users to comply with the general rules, for example, wear goggles and mask when soldering. All tools must be put back to their original positions after using and housekeeping while and tidiness in workshop help to minimize accidents. A safety manager is elected among teammates who is responsible to create a good safety culture in the company. The Operational and Safety Checklist can be accessed to in Appendix 1.

3 Safety Features

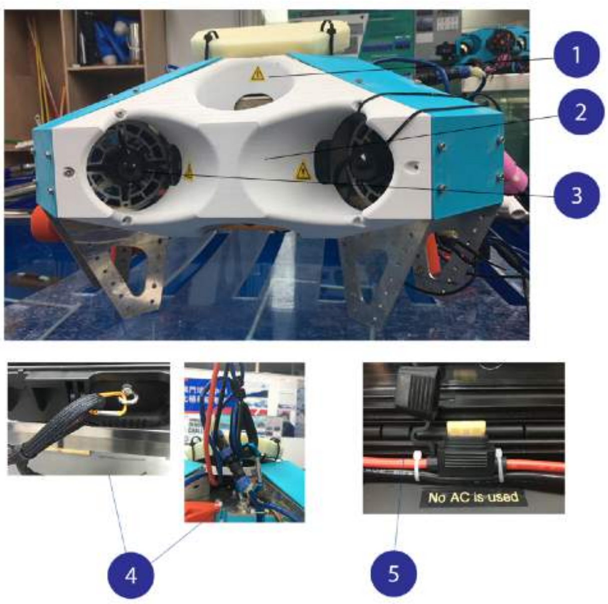


Fig. 36 Safety features of Nirvana

1. **Warning labels**: Warning labels are added on the moving components to caution against potential dangers
2. **Free sharp edge**: All sharpened edges were removed with the filleted and chamfered techniques to prevent injuries
3. **Thruster shrouds**: To prevent objects swirling into the thrusters
4. **Strain Relief**: A cable thimble is added for a proper strain relief.
5. **25A fuse**: For over-current protection

VI Schedule & Team Organization

1. Project Management

	Task Description	Task Category	Task Duration (hours)
1	Brainstorming Ideas	Whole team	100
2	Structure Design	Mechanics	144
3	Shell	Mechanics	125
4	Underwater Control System	Electronics	150
5	Camera System	Electronics	90
6	Propulsion system	Electronics	30
7	Waterproof test of Electronic enclosure	Mechanics	30
8	Control box	Electronics	108
9	Tether	Electronics	30
10	Prototype of Nirvana	Mechanics	108
11	Improvements of Design structure	Whole Team	150
12	Tools	Mechanics	108
13	Improvement of Tools	Whole team	150
14	Improvement of Electronics system	Whole Team	250
15	Image recognition system	Software	120
16	Micro-ROV	Mechanics	90
17	Technical Document	Public Relations	250
18	Pilot training	ROV Operation	350
19	Regional Competition	Whole team	80
20	International Competition	Whole team	120
21	Total Working Hour		2583

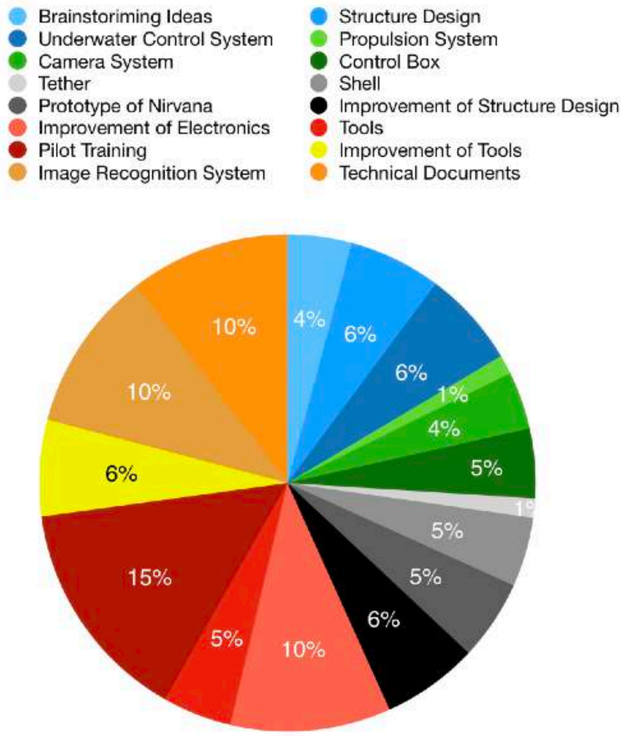


Fig. 37 Project time allocation

The ROV building process is never an easy job alongside studies of team members, hence good time management skill is essential. Tasks are allocated to the team members in accordance with their position, strength and interest. Weekly meetings are held and members are asked to hand in a summary of the task or work they have done each week and how to efficiently handle the resources they have been allocated, so that everyone knows the work progress and sticks to meeting each target under the limited budget. Together, we worked for approximately 2583 hours (Fig. 37) from sketching, planning, building and training since September, 2018.

2. Team Organization and Assignments

The Phoenix is divided into four departments: Electronics, Mechanics, Public Relations and ROV Operation (Fig. 32). Members of each department are responsible for reporting their daily progress to the department leader while the leaders convey the information to the CEO so as to make sure everyone is in their position and works efficiently. Apart from the CEO, the other posts like CFO, CTO and QCO are set to tackle other specific tasks such as accounting, technical aspects development and quality control. All teammates are motivated to exercise mutual coordination and cooperation to guarantee missions to be completed within schedule. The pilot training plan can be referred to in Appendix 2.

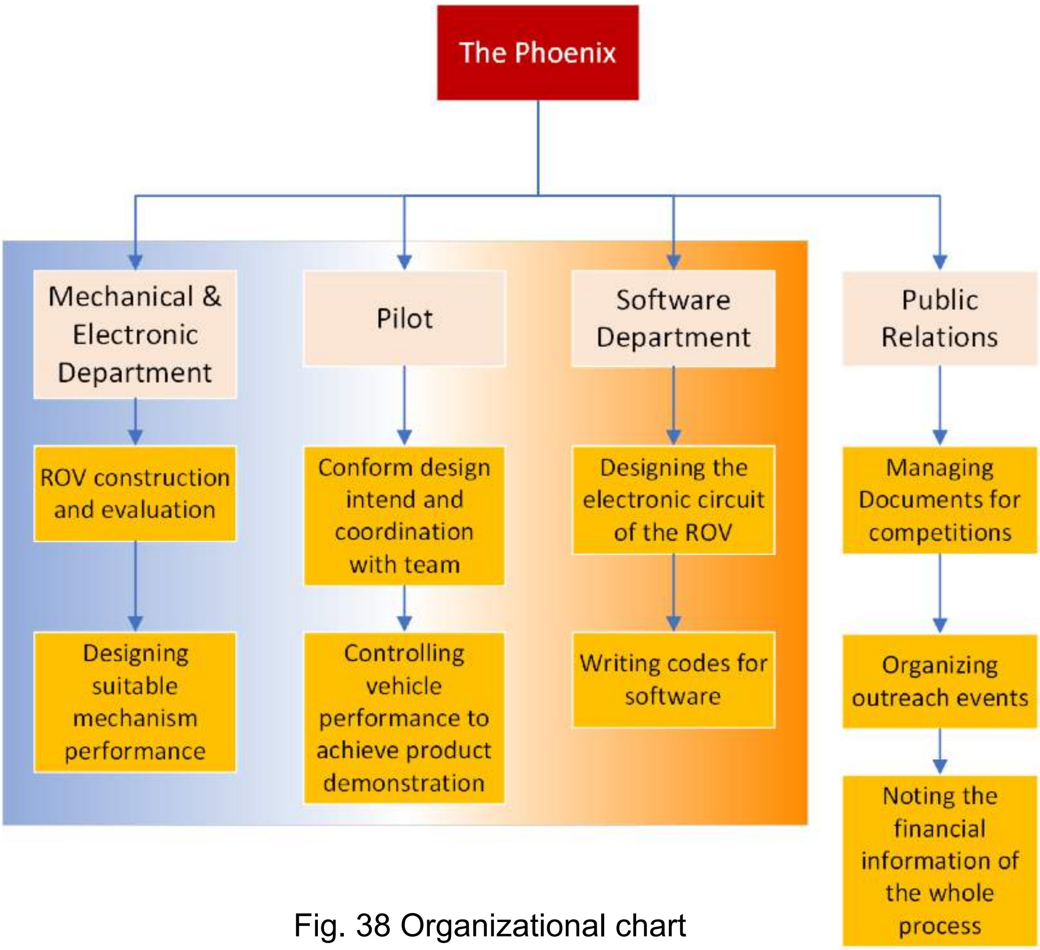


Fig. 38 Organizational chart

VII. Critical Analysis

1. Testing and Troubleshooting

A prototype of the ROV was built early last October in the pursuit of discovering any potential fault in the structural design. The center of gravity has been lowered to ensure the stability of our ROV while the wiring design has been added and improved gradually. The final frame has actually undergone 4 versions, each improving step by step.

Fig. 39 Performance evaluation

The performance of the vehicle largely relies on three factors: (i) waterproof of the underwater control system, (ii) compatibility among the computer, onshore control system and underwater control system, and (iii) the pilot's familiarity towards the ROV's functions and his proficiency in carrying out the missions. Hence, a testing protocol focusing on these three aspects is developed to minimize the time for debugging the failure.

Firstly, a hand operated vacuum pump is used to examine the pressure in the watertight enclosure to ensure it is properly sealed up and water will not leak in. At the same time it starts with the set-up of the ROV to safeguard it is ready for the dry run. Then, a dry run of the different parts of Nirvana is carried out to prove its normality and test its functionality before our ROV actually launches (Fig. 38). Apart from further verifying the waterproof of the enclosure and the compatibility of the operating system with the tools, the pilot can get familiar with Nirvana's manipulation and tools and enhance his manoeuvre skill and his ability to tackle problems that arise in the trial. A troubleshooting flowchart is shown below (Fig. 40)

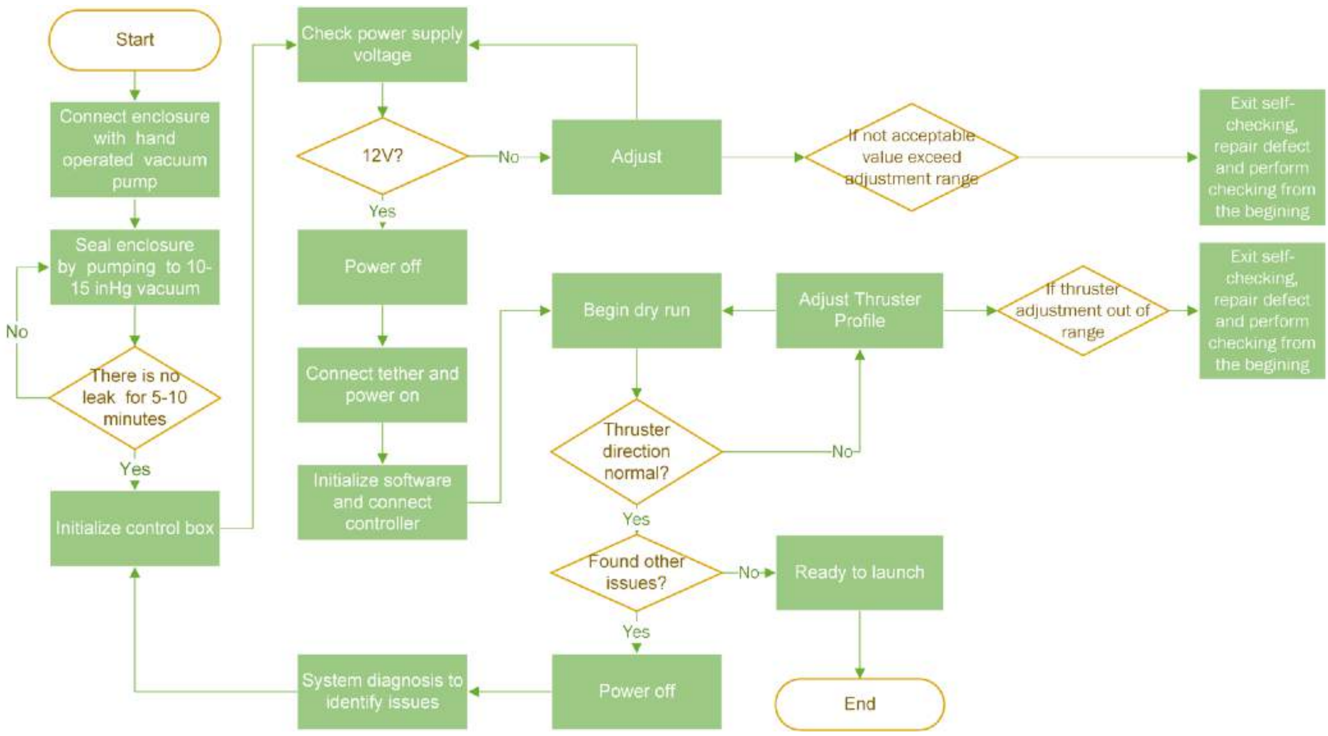


Fig. 40 Troubleshooting Flowchart

2. Challenges and Lesson Learned

2.1 Technical

Several technical challenges were encountered and overcome which contributed to the improvement of our ROV. Firstly, when using the image recognition system, noise jamming has been our priority concern as it affects the accuracy and effectiveness of our detection.

A noise reduction function is added to eliminate unwanted micro particles, hence enhancing the accuracy of the detection.

During the process of ROV operation, the grout and trout fry container was re-designed (Fig. 41). In our initial design, the container has the same size as the void, which our pilot has to spend a lot of time on the alignment of the two containers. We did not immediately re-design our container, and lots of time was spent on training the pilot. At last, we decided to change our design, but the pilot had to spend a certain amount of time adjusting to the new tools, which greatly affected his training plan. We learned a great lesson — we did not follow our troubleshooting protocol rigidly. If we had had applied seriously the protocol, we would have re-designed the container earlier and lots of time could have been saved. Since then, we have learnt that the troubleshooting flowchart is actually essential and by following it troubles can be tackled rapidly and efficiently.

Before **After**

Fig. 41 Evolution of container

2.2 Interpersonal

It is quite a challenge for teammates to strike a balance between ROV building and academic studies, especially when it clashed with tests and examinations. Some of the teammates may get stressed which resulted in lack of motivation. After several tentatives dealing with the different factors which caused low motivation, we found out that encouragement among teammates was essential and most effective in our team. Teammates were encouraged to speak positively to one another, avoiding sharp words and criticism. A peaceful, happy and collaborative environment was built up, so unmotivated teammates gradually found support in the team and turned to become a more motivated and productive way.

Good leadership is one of the most important factor for the success of a team, and it is a skill that every single leader has to master to enhance the global effectiveness. Hence, workshops were organized by the Phoenix not only to promote team cohesion but also to train members to be good leaders. Organization skills and communication skills are the experience we acquired the most in these workshops (Fig. 42). Each teammate was responsible to lead a team and organize the participants to complete their first ROV. With this experience, teammates were able to get familiar and know the difficulty in team

Fig. 42 Teammates leading participants

building, hence encouraging them to be more active and helpful in team work, which is considered not only as a great contribution to the improvement of our team but also a useful instrument in their later career pursuit.

3. Future Improvements

Nirvana has already gone through several improvements and transformation and came out finally with an outer casing composed of several geometrical patterns projecting the image of an UFO. The Phoenix's next step is to commercialize Nirvana, by simplifying the inside structure and minimizing its weight. With the success of commercializing Nirvana, the Phoenix aims at promoting ROVs to the public while arousing the awareness of marine pollution.

VIII. References

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IX. Acknowledgments

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- Our families: for their understanding and mental support
- Alumnis: for supporting our travel expenses
- Solidworks: for sponsoring our sketching software

X. Appendices

Appendix 1 - Operational and Safety Checklist

In the workshop:

- [ ] Approprate PPE is worn
- [ ] Working area clear, equipment and tools in the right position
- [ ] Make sure the floor and table is neat and dry before working

3D printers

- [ ] Do not touch the printing board before cooling
- [ ] Use approprate tools to remove printed objects

Soldering

- [ ] Clear table before soldering
- [ ] Use goggles and masks
- [ ] Use a piler if necessary

In the pit:

- [ ] Approprate PPE is worn
- [ ] All screws are secured and thruster shrouds are attached
- [ ] Keep power supply away from water
- [ ] Onshore testings done (Cameras, thrusters)

ROV launch and retrival

- [ ] ROV launches
- [ ] Buoyancy test
- [ ] Start mission
- [ ] Mission complete, ROV is driven to the side of the
- [ ] Turn off power of ROV
- [ ] Carry ROV to surface, use a fan to blow off water

Responsble person:
Comments:

Appendix 2 - Pilot Training Plan

Pilot Training Plan

THE PHOENIX	
Pilot	Sebastien Sin
Date	2019 / 04 / 13
Timing	11 : 00 AM
Training Content	Task 1 : Inspect Foundation of dam, insert grouts and voids, Remove and replace trash rack Task 2 : Monitor water quality, water sample, habitat diversity trout fry, lift rubber tire Task 3 : measure the cannon, lift cannon, Identify cannon shells with a mark
Situation Analysis	Micro ROV's tether strangled with main ROV's tether Sudden disconnection within ROV and QgroundControl
Total Score	Mission 1: 55 / 90 Mission 2: 90 / 90 Mission 3: 70 / 90
Suggested Improvements	Double check connectors of Ethernet cable tether deployer should be redesigned
Mentors Suggestions	- Pilot should do more practice in ~~sh~~ school before heading to the standard swimming pool, enhance the efficiency