RECCD

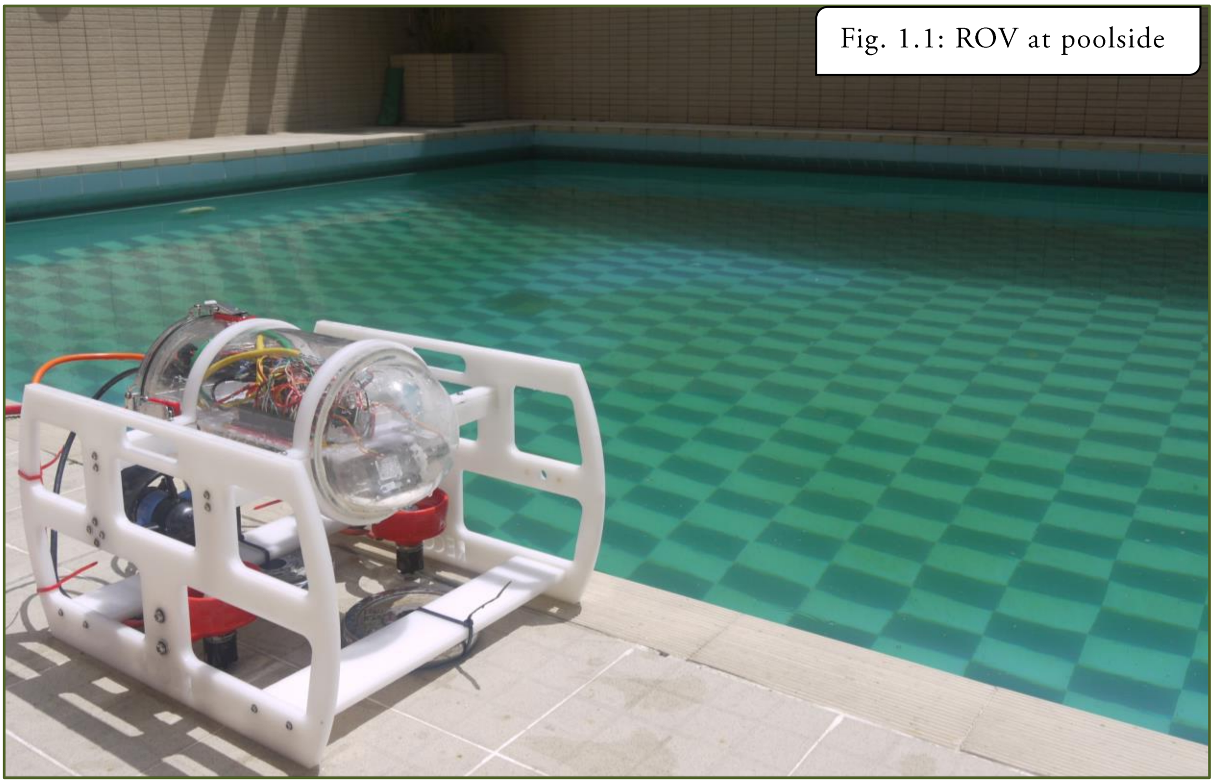

Fig. 1.1: ROV at poolside

Company Directory

Hugh Somerset, ***Class of 2017***
Chief Executive Officer, Chief Engineer

Hain Yoon, ***Class of 2016***
CAD Engineer, Safety Officer

Matthew Zhang, ***Class of 2016***
Engineer

Maxine Kwan, ***Class of 2016***
Chief Financial Officer, Product Sourcer, Engineer

Cheryl Chan, ***Class of 2016***
Programmer, Logistics & Documentation Officer

Roger Lau, ***Class of 2017***
R&D Officer, Engineer, Pilot

John Shearman, *Mentor*

German Swiss International School

Company Name: RECCD

Location: Hong Kong, Hong Kong

Technical Documentation

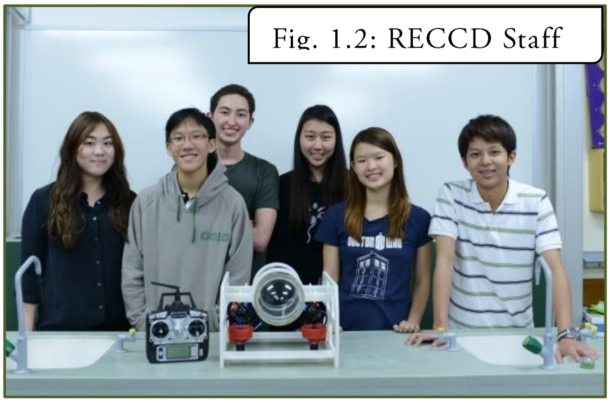

Fig. 1.2: RECCD Staff

From left to right: Cheryl, Matthew, Hugh, Hain, Maxine, Roger

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Abstract

Real-time Exploration Controlled Craft Development (RECCD) is a small German underwater robotics company based in Hong Kong. Since October 2014, our six members of staff have been developing and testing our newest remotely operated underwater vehicle (ROV), *Die Meduse* (German for *The Jellyfish*). *Die Meduse* was designed with the specific goals of accomplishing missions related to science under the ice, subsea pipeline inspection and repair, and offshore oilfield production and maintenance, all in an arctic environment. After an eight-month period of thoughtful and thorough design, development and testing, our dedicated and talented team has produced a compact, safe, reliable and cost-effective ROV to complete all the missions in extremely cold conditions to demonstrate its functionality in polar science and marine exploration.

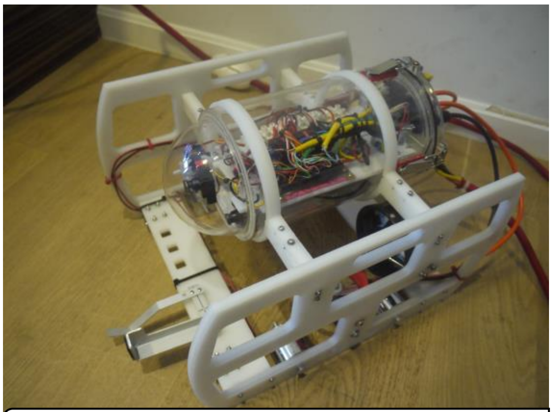

Fig. 1.3: Die Meduse

Die Meduse's in-house CAD-designed chassis is laser-cut out of 10mm-thick polypropylene. Attached to the chassis are four performance-optimized brushless motors, controlled with great precision with joysticks from the surface, interchangeable hooks and payload tools, and a re-sealable domed watertight compartment (WTC). The WTC houses our cameras with distortion-free lenses and four electronic speed controllers. A thin and flexible 18-meter tether with two signal cables and two 10AWG cables connect the ROV to the surface. These features, designed carefully for use in the field of polar science, make *Die Meduse* the ideal choice for prospective customers.

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Company Mission

At RECCD, we are dedicated to the development of high quality, purpose-built ROV systems for our customers. With a passion for marine exploration, our aim is to deliver simplistic, elegant engineering solutions that provide high performance at affordable prices. Through well-considered design and rigorous testing, we guarantee to produce highly operable and consistently reliable systems.

Design Rationale & Vehicle Systems

As a mainly new team, we needed to conduct thorough research on existing ROVs and their designs to begin our design process. We accomplished this by observing and analyzing professional ROVs such as those created by Seabotix and Crustcrawler as well as reading the technical documentation of companies similar to ours. From this we learned our ROV should be light, hydrodynamic, and compact, yet still be able to accommodate all of its devices which include cameras, thrusters and payload tools.

Chassis

Die Meduse's chassis was the first key feature of the ROV to be designed. The following points outline the steps we took in designing the chassis:

1. Research existing ROV designs and features
2. Brainstorm and decide on what components must be attached to chassis.
3. Brainstorm different chassis designs that accommodate all the components.
4. Decide which design is most efficient and achievable.
5. Edit out any imperfections in design, ensure enough space for all components and leave some room for possible extra components that may need to be added.
6. Decide what material to use for the chassis.
7. Design, manufacture and test chassis prototypes.
8. Improve design and manufacture final chassis.

We determined that our chassis needed to hold two vertical and two horizontal thrusters, payload devices at the front and a watertight compartment. During the design sessions, we decided the most efficient way of attaching all these components was by having two vertical boards on either side of the ROV connected by beams..

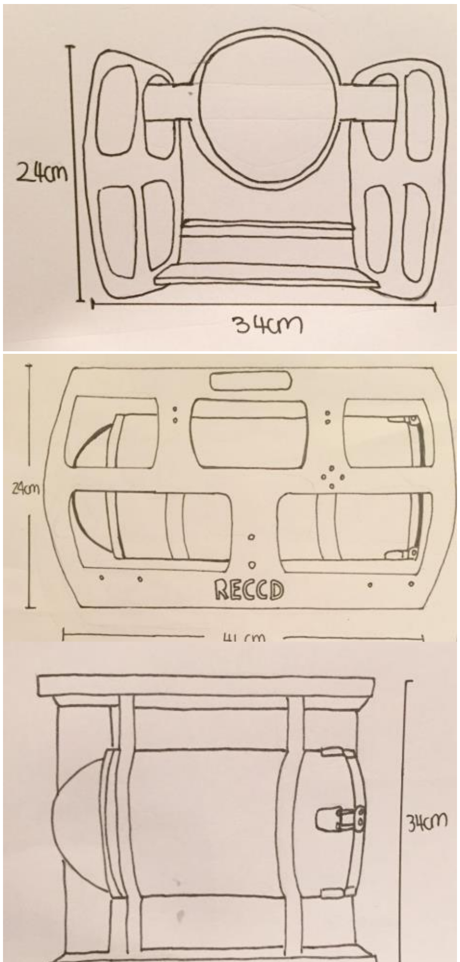


Fig. 2.1: Initial design sketches of Die Meduse

After thorough analysis of the materials available, we determined that polypropylene was the most suitable for the chassis. With its density of 946.00 $kg\,m^{-3}$, the chassis is extremely light, with near-neutral buoyancy in water. The cost-friendliness of polypropylene meant that the chassis only cost approximately HK$300 (≈US$38.46).

In comparison with acrylic, polypropylene is lighter and much less brittle. Our chassis is therefore less prone to cracking, whilst still being easy to drill through and cut. Polyvinyl chloride (PVC) pipes for the chassis were also considered, but its round shape would cause difficulties when attaching other components and its hollow interior would take up unnecessary space. Its appearance also lacks the sleekness and professionalism of laser-cut polypropylene. In addition, an aluminum chassis was found to be too dense, more difficult to cut and drill through than plastics.

Laser-cutting the chassis was chosen for its superiority in accuracy compared to cutting polypropylene by hand. Therefore, the two sideboards are identical and all components are accurately positioned on the chassis. As we do not have in-house laser-cutting facilities, the chassis was designed on 2D-CAD software by our CAD Engineer Hain Yoon, who developed 2D-CAD skills on LibreCAD from scratch in October 2014. The chassis was then cut by a laser-cutting service provider in China. All components were designed to be packed as closely together as possible without blocking any water flow from the motors, resulting in final chassis dimensions of only 0.40 x 0.25 x 0.35 m.

Watertight Compartment (WTC)

When developing the design of *Die Meduse*, it was evident that a re-sealable watertight compartment would be essential for the storage of electronic components and to provide the required flotation for neutral buoyancy. The WTC of *Die Meduse* consists of an acrylic cylinder, 0.24 m in length and 0.15 m in diameter, an acrylic dome is glued to its front to decrease water resistance. The re-sealable lid of the WTC was created from three pieces of laser-cut acrylic glued together. A 5 x 10^{-3} m thick nitrile O-ring creates the seal. The lid is held in place by four latches. Latches were chosen over nuts and bolts as latches take much less time to open and close, and they are clearly visible to the human eye from afar to determine whether they are open or closed. The contents of the container include four brushless electronic speed controllers (ESCs), a servo-mounted front-facing camera and a 12V to 6V step-down voltage regulator.

Fig. 2.2: Back of WTC lid

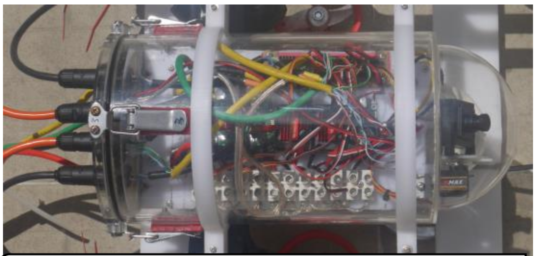


Fig. 2.3: Inside of WTC

Tether

Die Meduse's tether is 19m long, containing two 10AWG cables and one CAT5e cable for camera signal and one 12-core signal cable for the control system. With only four cables, the tether is extremely thin, allowing for us to minimize drag and maximize ROV speed. The flexibility of the tether was crucial in preserving the turning capabilities of the ROV. Each cable is a different color so that they are clearly distinguishable from each other.

The CAT5e cable was chosen because of its low cost. We chose multi-strand wires over single-core ones as it makes the cable much more flexible. Furthermore, we chose a shielded signal cable instead of a CAT5e cable for our control system, as we discovered from our first tether design that shielding is necessary to prevent signal noise interference to our PWM signals. To provide power for *Die Meduse*, two copper 10AWG (2.59 x 10^{-3} m in diameter) cables are used, since they are thick enough for minimal voltage drop, yet thin enough to keep the tether thickness down, yet remain flexible due to their quality silicon insulation.

Fig.2.4: Tether on Reel

The nylon wire sheath serves to hold the four cables together securely. It has advantages over cables ties or a wrapping band cable cover, because it adds less thickness and is much better at holding the cables together throughout the tether consistently, as well as being highly flexible and cost-friendly. Furthermore, fishing net floats are attached to the red nylon wire sheath to provide the tether with neutral buoyancy. Advantages of using these floats include their extreme buoyancy and lack of water soakage, unlike pool noodle floats. To fit them around the tether, we divided each float into two pieces with our in-house built and designed nichrome wire cutter.

Motors

To minimize current draw from the battery, which would result in a greater voltage drop through the tether, we chose to only have two upward-facing and two backward-facing thrusters as fewer thrusters will draw less overall current. These four thrusters provide us with three degrees of freedom, which we felt served our purposes well for marine exploration.

Fig. 2.5: T100 Thruster

Die Meduse uses four Blue Robotics T100 brushless thrusters for horizontal movement, purchased from their Kickstarter campaign at US$100 each. Each thruster creates 13.6N of thrust at 5A. These professionally optimized thrusters provide our ROV with powerful thrust without having to spend over US$500 for costly alternatives such as those offered by Seabotix.

An alternative to the T100 thrusters was a RC brushless outrunner motor with a 3D-printed propeller and shroud. Upon testing, these were powerful, capable of producing 9N of thrust at 10A. However, its electrical current-to-thrust efficiency was inferior compared with the T100 thrusters and so are not featured in our final design. 1100 gph (1.16 x 10^{-3} $m^3 s^{-1}$ in SI) bilge pumps were also considered, since they are simple to control being brushed DC motors and already waterproof, however they are heavy and large in size, with their cylindrical shape making them difficult to mount onto the chassis.

Control System

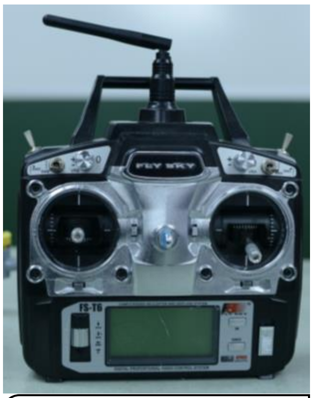


Fig. 2.6: Pilot's Transmitter

Unlike last year's ROV *River Song*, a switch-based system is no longer used to control our ROV. Instead, by using pulse width modulation (PWM) to control the ESCs on *Die Meduse*, we now have precision control of the ROV as we can vary the speed of the motors. One hobby RC car ESC was used per motor, since they are compact, affordable and provide bi-directional control of thrusters. Unfortunately, RECCD does not possess the facilities or the knowledge to create an in-house brushless motor driver system. Furthermore, purchasing ready-made ESCs provide high reliability and safety, which are crucial when dealing with high current systems.

A joystick-based RC airplane transmitter is used as a controller, allowing for very precise control and easy calibration. Chosen for its ease of use, high sensitivity and reliability, the transmitter communicates the position of the joysticks, with up to six channels (four are used), to the receiver inside the control box wirelessly via a 2.4GHz radio connection.

Video System & Cameras

Die Meduse has three onboard cameras, one which provides a front view and the other a side view. The front view camera is placed in the watertight compartment (WTC). Mounted on a servo, the HD camera can be rotated up and down by the pilot to fully visualize the ROV's surroundings. This functions as the main navigation camera. It also serves as a downward-facing camera for searching and identifying starfish and as an upward-facing camera for locating and collecting floating algae.

Fig. 2.7: Front-facing camera

The side-view camera looks out the right side of *Die Meduse.* It is housed inside a transparent in-house built acrylic case and has been waterproofed by potting with epoxy. This camera's main use is for conducting close visual inspections on pipelines, as its positioning allows the ROV to move parallel to the pipe while inspecting for corrosion. It also assists in navigation, as the side view helps prevent the pilot from becoming disoriented.

We also have one waterproof fisheye lens camera positions on the same level as our payload tools. This gives us a wide angle view of our tools for performing tasks. We discovered this was necessary when doing pool training and found that the driver found it difficult to use the payload tools with the front facing camera in the WTC because of the parallax error that occurs.

Control Box

On the surface, we have one splash-proof control box containing all its core components, making the control system simple to transport. The dimensions of the control box are 0.05m x 0.38m x 0.20m, making it large enough to accommodate all components, yet small enough for one person to carry by hand. It contains a TFT monitor connected via a mini DVR box to the cameras, two receivers for wireless communication with pilot and co-pilot's transmitters, a 25A car fuse, a safety switch for the entire ROV system, and a voltmeter and ammeter for the system.

Fig. 2.8: Control box

We decided to mount a disused TFT computer monitor in the control box as it means the entire ROV system is self-contained between the ROV, tether and control box. It also contains two music-playing speakers for entertainment and relaxation purposes.

Tools

The key features that allow *Die Meduse* to successfully complete the mission tasks are our carefully designed tools. These tools, in combination with our powerful thrust system, allow *Die Meduse* to perform tasks quickly and efficiently. After brainstorming methods of completing tasks we decided on the most efficient and reliable tools to complete tasks.

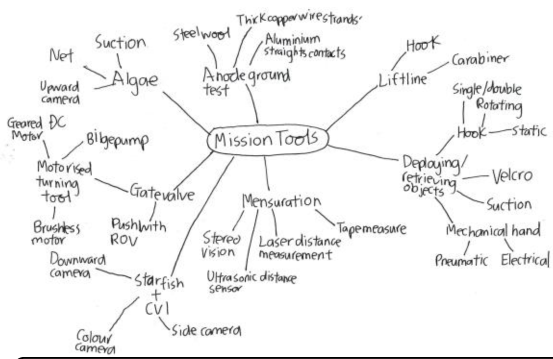


Fig.2.9: Brainstorm of Mission Tools

Hooks

After careful analysis of the mission requirements, we determined that many required tasks could be best completed with purpose-built interchangeable hooks. These attachments, hand-shaped from aluminum, are extremely lightweight, simple to use, affordable and very reliable. Our rotating hook is mounted on an IP67-certified waterproof servo, which provides the hook with 180-degree rotation. This allows objects to be hooked extremely easily when the hook is horizontal, be under control reliably when the hook is rotated upwards, and be dropped when the hook is rotated downwards. This user-friendly tool is specifically designed to retrieve sea urchins,

Fig. 2.10: Rotating hook

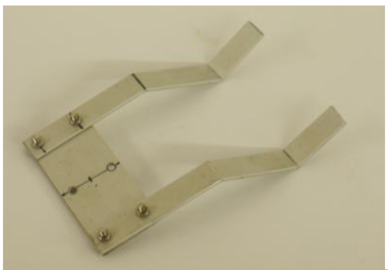


Fig. 2.11: Double hook

lift pins to cut corroded pipelines, and remove and replace a wellhead's protective cover and gasket.

We also utilize a static double hook to deploy passive acoustic sensors, insert hot stabs and insert bolts to secure flanges of cut pipelines. As it is purely mechanical, it is unlikely that it will malfunction, unlike grippers which are popular on other ROVs. This hook, therefore, also acts as a backup for our rotating hook. Our engineers experimented with various hook designs and finally decided on using an angled hook (Design C), as it uses gravity to force the hooked object to stay in place while being easy to unhook off objects for deploying. Although humble in appearance, our hook is foolproof and serves our purposes extremely well.

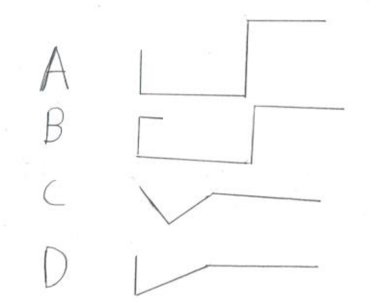


Fig. 2.12: Hook designs

Net

To retrieve an algae sample from under the ice sheet, we created a small net with a rectangular opening made from bent aluminum. The topside of the opening is made flat and filed thin, so that it can press up close against the ice sheet and catch an algae sample. Once in the net, the positive buoyancy of the algae will cause it to float vertically above the opening of the net, preventing it from falling out. A suction device to retrieve the algae was considered by our engineers, however after testing we found that it was ineffective in attracting the algae as its effective range was too small.

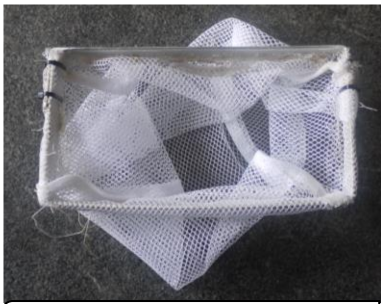


Fig. 2.13: Algae Net

Gate Valve Manipulator

The tasks of turning a gate valve to stop oil flow and to redirect water through a pipeline demand a reliable and fast gate valve manipulator. Initial experimentation showed that using the ROV to turn the valves by pushing the beams was inefficient and difficult. In the face of this challenge, we designed a manipulator with a geared DC motor that spins at 50 revolutions per minute, which can completely close or open a gate valve within 7 seconds. We needed to use a geared motor to achieve enough torque; a bilge pump was also tested out but did not have the required torque to turn the valve.

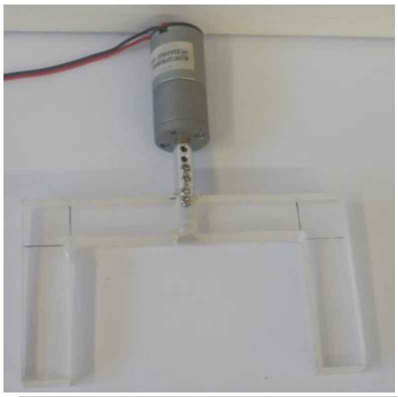


Fig.2.14: Gate Valve Manipulator

Anode Grounding Test Tool

Fig.2.15: Test contacts

To test the grounding of anodes along an oil platform's leg, we developed a custom contact interface connected to a voltmeter on the surface for measuring voltage across the anode and common ground. The contact interface is made of two steel wool balls: one to contact the anode, the other the common ground. As the platform legs are cylindrical, the steel wool is held in an arc shape by bent aluminum strips to have a wrapping fit onto the leg. Steel wool was chosen as it provides high conductivity and high surface area contact that does not slip when pushed against the anode, unlike conventional metal contacts.

Removable tool interface

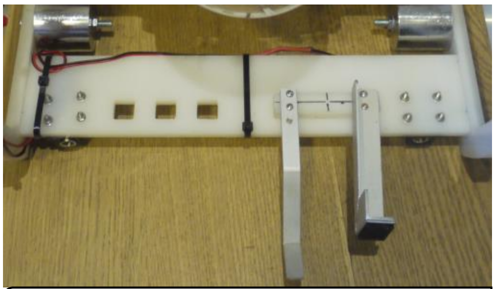


Fig.2.16: Left and Right Tool Slots

We are extremely proud of our innovative and intuitive tool attachment system which allows for easy exchanging of payload tools on the ROV in a matter of seconds. The design involves three square slots on the front horizontal plate of the ROV chassis, which accommodates a tightly laser-cut "key" bolted onto all of our tools. Thus our payload tools can be firmly attached to the chassis whilst being easily removable. In order to carry two sets of tools concurrently, we have two sets of holes on the front of the chassis. This saves us valuable time so that we do not have to exchange payload tools during missions as often, whilst making the entire system much more modular, allowing for additional tools not accounted for in the original design.

Acquisition of Skills

Four out of our six members of staff are working with ROV systems for the first time. Prior to joining, they had encountered neither hand and power tools nor electronics tools. With the guidance of the two more experienced members of staff, they learned how to use them safely and efficiently over the course of eight months. As a result, the entire team is now confident in using soldering irons, power drills, jigsaws and drill presses, as well as common hand tools. We have also increased our skills in operating electronic tools such as the digital multi-meter, various power supplies and oscilloscopes. From having to follow step-by-step instructions to being able to complete tasks and achieve goals independently, we have developed into a capable, cooperative and skilled team, able to carry out complex tasks and make decisions with confidence.

Software Flowchart

Although our control system contains devices with built-in software, we at RECCD ensure that we have a thorough understanding of how the software in our systems work.

We believe that our dedication towards understanding every system of *Die Meduse*, no matter how minute, is what makes us a prime company. Familiarity with the software also aids us in troubleshooting and allows us to harness the full potential of the software.

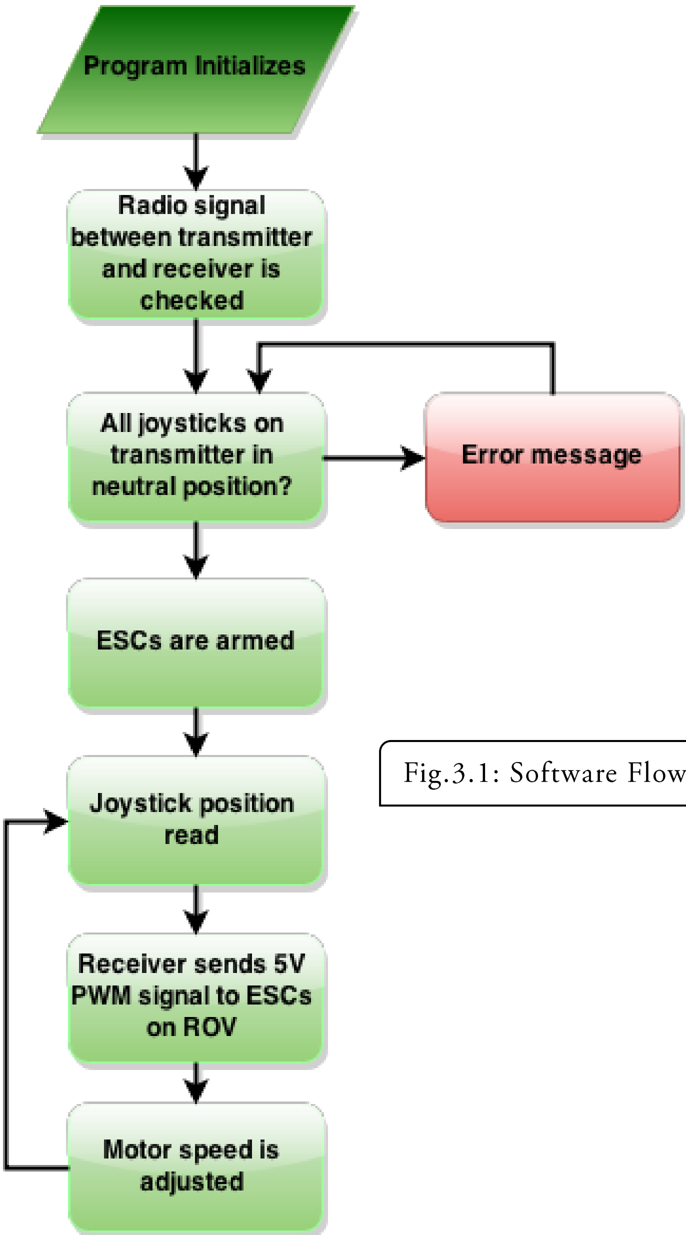


Fig.3.1: Software Flowchart

Re-use of materials

Our policy at RECCD is to avoid reusing components from previous years. This is because old devices are generally not optimized for performing the required tasks, as they were designed originally for different purposes. More often than not, old components have not been maintained for long periods of time and are therefore less reliable. Also, as a company looking towards the future for innovation, our work and quality standards have increased hugely and most of our past developments no longer meet our quality standards. All the components of the *Die Meduse*, including the chassis, motors, WTC, and control system were newly designed and purpose-built. This allows them to be most suited to this year's mission.

Factors we considered in our decision making process to reuse materials included cost-saving, environmentally friendliness, suitability to this year's system and performance relative to using a new component. By using this process, we decided to reuse wires for wiring in our control box and ROV as there are no drawbacks from doing this. We also decided to use a second hand disused monitor in our control box instead of purchasing a new one which would be wasteful and have cost a lot of money.

Troubleshooting Techniques and Testing

The three features of the ROV that may require troubleshooting are our control system, camera system and watertight compartment. Therefore we have designated practical and efficient troubleshooting techniques for each of those three systems. Our troubleshooting process involves the following steps:

1. Identify and isolate the issue.
2. Brainstorm possible solutions.
3. Execute the most practical solution.
4. Check whether or not the solution has solved the issue.
5. If the issue persists, identify the reason and find an alternate solution.

We performed thorough testing on our entire vehicle by deploying in our pool multiple times. Before placing it in water, we would test each system of the ROV by checking all motors, cameras and the rotating hook, we would then repeat the test with the ROV in water. Each component was also tested in the lab prior to be deployed in the pool.

An issue arose with our control system during testing, where one motor suddenly stopped spinning and could not be turned on. Because of the numerous possible causes we followed our troubleshooting methodology to solve the problem. To isolate the issue, we first checked that adequate power was reaching the ESC of the motor and the transmitter; both were functioning correctly. With an oscilloscope, we then probed the signal output from the receiver and observed a PWM signal coming out of it at 5V meaning it was functioning correctly. However, on the ROV, the ESC was not receiving the same PWM signal. We checked both ends of the tether connectors and found that the CAT5e cable carrying the signal had been badly crimped onto the 8P8C connector and one of the wires had come loose. Resolving the issue was then a simple matter of cutting of the connectors and crimping on a new connector with great care. We then tested the full system, finding that the problem was resolved and for good measure we also checked all other connectors for poor crimping afterwards.

Safety

Our Safety Philosophy

Safety is our priority at RECCD. In adherence with our mission to develop efficient, usable systems, we ensure that our products are safe to use even with minimal training.

We believe that no safety issue should ever be ignored, we employ this philosophy in our work habits and in our final product. Through extensive testing, we have determined that our ROV meets all and in some cases even exceeds certain modern safety standards.

Safety Practices

We take great pride in the efforts we take to ensure the safety of our engineers and those around our ROV when operated. At the beginning of the year, all members were taught and reminded periodically how to properly operate potentially dangerous power tools, including soldering irons, jigsaws, drill presses and power drills. Each member of the team is now confident in their power tool skills that were involved in developing our ROV. Protective equipment, including safety googles, gloves and hearing protection is always worn when operating power tools. Long trousers and closed-toe shoes are worn at all times when in the working space. Visitors are allowed in the working area or near the ROV system only when supervised by a member of staff.

Safety Checklists

Throughout the design and development of *Die Meduse*, our dedicated Safety Officer, Hain Yoon, produced a safety checklist to be checked and followed while working:

Safety Checklist for Working	Checked
Appropriate attire is worn: closed-toe and closed-heel shoes.	
Long hair is tied back.	
Gloves are worn when handling epoxy.	
Ensure that the floor of the working area is clear of obstacles and trip hazards.	
Hearing protection and ANSI-approved non-shaded safety glasses are worn when operating power tools.	
Never handle a power tool by its cord.	
Tools are clean.	
Spotter is present when a power tool is being operated.	
Parts to be drilled/sawed/routed are securely clamped or in a vice.	
Lead-free solder is being used and area is properly ventilated.	

Safety Checklist before Deploying ROV	Checked
All items are securely connected to *Die Meduse.*	
No cables are loose or unplugged.	
Both ends of the tether are properly plugged in.	
O-ring has been greased and thoroughly checked for dirt/hair.	
All motors work.	
All cameras work.	
ROV is securely connected to 12V DC battery.	

Safety Checklist when Operating ROV	Checked
Die Meduse is only carried by the specially designed handle.	
Always at least one staff member directly watching ROV when in water.	
Pilot always has hands on controls.	
Pilot is always watching live camera feed while driving ROV.	
All people in vicinity are aware that the ROV is being deployed.	

Furthermore, numerous safety features are present on our ROV to ensure it does not cause any harm or damage to its surrounding environments when being transported or operated.

Die Meduse's Safety Features

- All propellers are completely shrouded and within *Die Meduse*'s chassis.
- No part of *Die Meduse* sticks out from the chassis.
- No sharp corners or edges (hence RECCD's choice to forego the use of metal for the chassis)
- 25A fuse for the entire system.
- No exposed wiring.
- All splices (solder connecting two wires) and solder connections are insulated with heat-shrink tubing and waterproofed with two-part epoxy and thoroughly inspected.
- All components are securely attached to the chassis.
- Wire color-coding is consistent throughout the system to prevent connecting devices in the wrong polarity; red is always used for positive and black for negative.
- One-way connecters are used whenever possible, so devices cannot be connected in the wrong polarity.

Incident

Although we have taken every measure to ensure that *Die Meduse* is as safe as possible, we acknowledge that occasionally we had oversights on certain occasions.

A notable incident that took place at the very beginning of the project is when one engineer, Matthew Zhang, was working with a jigsaw to cut thick acrylic and forgot to wear safety goggles. When he began cutting the thick acrylic, shredded plastic flew in all directions. This could have damaged his eyesight if any remnants had gotten into his eyes. After this incident, we assigned Hain Yoon as our Safety Officer to conduct safety checks before each work session to ensure that everyone knew and followed the correct safety procedures.

Challenges

Technical Challenges

One of the most prominent technical challenges we encountered during the design and development of *Die Meduse* was the waterproofing of our WTC lid. This was an essential part of the system, which had to be flawless to ensure our ROV functioned correctly.

Even after spending countless hours on developing and checking the design, the first few prototypes did not seal the container properly. One major issue with the first prototype lid was that the O-ring was not being squeezed enough, because the inner diameter of the WTC tube was 143mm instead of 140mm, which was the specification from the manufacturer. This was solved by redesigning our lid to match the true tube diameter. From this experience, we learned not to blindly trust manufacturer's specifications and to perform our own measurements. Through the process of developing a watertight compartment, we learned to produce 2D-CAD designs for laser-cutting, as well as the concept and usage of O-rings, which are both extremely useful skills in the field of underwater robotics. Finally, after weeks of development, WTC lid 1.4, our fourth prototype, successfully prevented any water from entering the WTC for a six-hour period.

Non-Technical Challenges

Organization of materials was a significant non-technical issue this year. Our company had to share our working space with another company based in German Swiss International School. This posed a challenge, as tools and storage space would be shared between the teams, but each team's building materials needed to be kept separate. At the beginning there was often confusion of between the two companies as to who owned what, due to poor communication. This led to materials going missing or being used by the other company. One notable example was when one of our engineers Maxine Kwan spent two hours cutting an acrylic board for our control box. The next week, we found the other team had cut out a section, believing that it was a scrap piece of acrylic. This created a massive waste of manpower as we had to repurchase and re-cut another acrylic board. After this incident, we allocated separate shelves and areas for each team to store their materials. In addition, we labeled all our materials clearly. This prevented all future confusion and allowed our two companies to share the same space effectively.

Lessons Learned

Technical Lesson

A key skill we have acquired this year is 2D-CAD design. This allowed us to manufacture high-precision parts for our ROV, including the lid of our watertight compartment and chassis. Our CAD engineer, Hain Yoon, and chief engineer, Hugh Somerset, both learned and developed skills in using LibreCAD to implement our designs. This was a time-consuming but worthwhile lesson, as manufacturing a chassis by hand often results in crude-looking products and the creation of the watertight lid would not have been possible using laser-cut methods without CAD files.

This was also our first year making a re-sealable watertight compartment, and using CAD also increased the challenge of the task. Nevertheless, RECCD's engineers met this challenge with great enthusiasm. Working in a collaborative manner, we performed extensive research on O-ring materials, maintenance and installation processes to ensure a waterproof seal on our watertight compartment. We then began the design and prototyping stage, based on the information that O-rings should have a 30% stretch, 5% squeeze and fill 75% of its groove.

Interpersonal Lesson

An interpersonal lesson learned is that having a supportive and friendly work environment is crucial for prime productivity. We found that we could achieve much more during sessions when we were patient and understanding with each other, whilst being considerate when setting deadlines and clarifying expectations. By not pressuring others to produce a complete product in a rushed manner, we were able to produce higher quality products and develop greater interpersonal relationships, allowing us to collaborate much better as a team.

Company Effort

At RECCD, we value the fact that systems design and production is performed solely by members of our company. Whilst we are extremely grateful to all the moral support that we receive from our mentor and other individuals, we are also thankful that they allow us the independence we require for developing *Die Meduse*.

Team Assignments

To ensure maximum productivity, we set numerous deadlines in the development process of *Die Meduse.* This prevented us from devoting too much time to one area of work and neglecting others, and ensured that we could complete and test our ROV in time for both the regional and international competitions. Our deadlines were the following:

Assignment	Assigned Date
Introduction to power tools	15 Sep 2014
Complete chassis build	01 Jan 2015
Complete control system	01 Jan 2015
Complete camera system	01 Feb 2015
Test ROV in pool	01 Mar 2015
Complete payload tools	15 Mar 2015

Project Management

We use a number of protocols to ensure maximum productivity at RECCD. The structure of our work is set through long term and short them planning. Long term planning happened when we first began in September 2014 and also after winning the regional completion in April 2015. At those points we developed our team assignments and team schedule which we adhered. Short term planning was essential to have a strong work pace. At the beginning of each session, each member would set a specific goal they would achieve individually or in a pair by the end of the session, this gave us a sense of purpose during sessions and allowed us to gauge our work speeds. Our motivation came from taking short breaks during sessions to relax and talk before returning to work. After all our intentions are not only to learn but also to enjoy the process. However, not overworking ourselves did prove to make sessions more productive in the long run. Our protocol to overcoming problems was to brainstorm possible solutions individually, if unable to find a solution, consult one or two members of the team for their opinions. To find the ideal solution, we always brainstorm possibilities and then select the best solution based on performance and time consumption. Our resources were handled by CFO Maxine Kwan who throughout the year collected purchase receipts and logged team spending. We would analyze our spending at the end of each month and decide if we should be spending more, less or the same amount in the next month.

Schedule

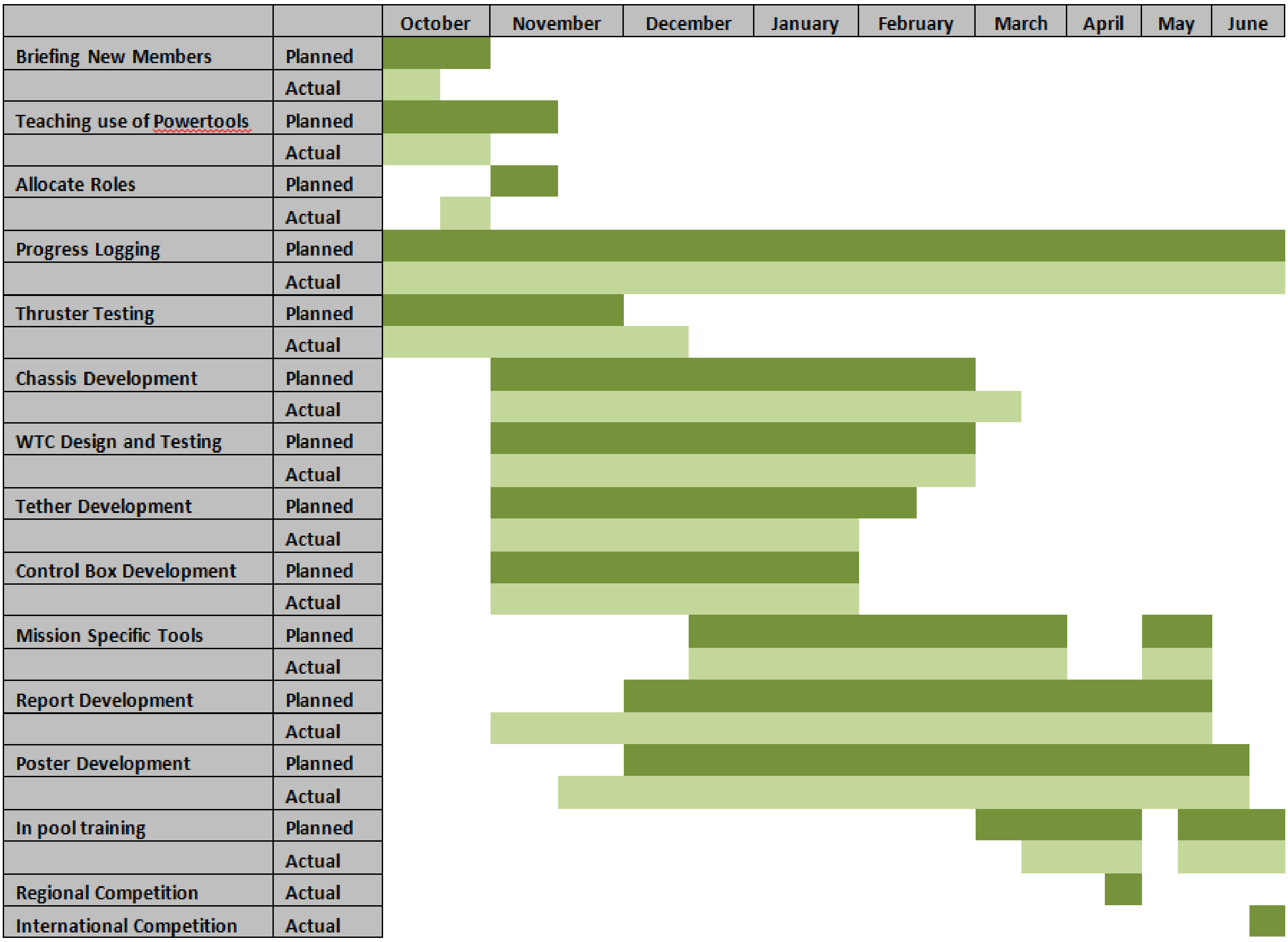


Fig. 4.1: Development schedule

We developed this schedule at the beginning of the year and updated it after winning our regional competition. Throughout the year we logged our process against our intended ambitions. We are happy to say that we were generally successful in keeping to our schedule and it was definitely a useful organization tool to have this year.

Future Improvements

Although we are extremely proud of the advances we have made in ROV development this year, we continue to search for ways to improve our ROV systems. Now that we have the ability to develop a functioning watertight compartment, in the future we hope to install intelligent sensors inside to monitor the ROV in the water. A gyroscope mounted in the compartment would allow us to have a real-time simulation of the movement and direction of our ROV, and would be extremely useful in aiding navigation in water by essentially eradicating the problem of pilot disorientation. Even more ambitiously, with a gyroscope our ROV could potentially correct any unwanted tilting or yawing of the chassis automatically. For safety, we would include a pressure and moisture sensor inside the WTC, which would alert us if the O-ring seal was compromised, allowing us to remove the ROV out of the water before any damage is sustained.

We firmly believe that we these improvements are fully achievable, given time and focus. Although they are not essential for a satisfactorily functioning ROV system, onboard sensors unlock a huge variety of possibilities to improve the operation of our ROV. We look forward greatly towards the opportunity of implementing these improvements.

Reflections

Hugh Somerset, *Chief Executive Officer & Chief Engineer*, Class of 2017

"Robotics and developing ROVs have been hugely significant parts of my life since I started two years ago. It's been an unforgettable learning experience that has taught me to envision and develop a long-lasting project from scratch and how to operate efficiently in a team. Through the process I've come out a much more pragmatic and analytical person than before. Our team of members mostly new to robotics took on an ambitious goal of developing a more technologically advanced ROV than ever before and I am proud of our attempt and of what we have achieved over the last six months."

Maxine Kwan, *Chief Financial Officer & Engineer*, Class of 2016

"The most rewarding moment during working on *Die Medusa* was when the laser-cut watertight compartment lid and laser-cut chassis arrived. We had worked extremely hard on producing these and seeing them in real life was incredibly satisfying. I had to communicate with numerous suppliers, compare prices and send them the specifics of our design to ensure that the products could be accurately made. After this experience, I learned to design and customize components according to our needs, and modifying them slowly until they satisfied our purposes. I was very active during the design process, since I was the main communicator between the suppliers and our team, and I hope to continue working with RECCD and the suppliers closely to produce the most useful components for future ROVs."

Cheryl Chan, *Programmer, Documentation & Logistics Officer*, Class of 2016

"My first year as part of RECCD was an especially rewarding experience. Not only did I have the rare opportunity to gain hands-on experience of working with ROVs, but being tasked with writing and overseeing the Technical Report meant that I had to gain a comprehensive understanding of all the workings of *Die Meduse*. Since everyone on the team was in charge of developing a separate aspect of the ROV, clear interpersonal communication and collaboration was key to ensure that everyone was fully aware of what the others were working on. I thoroughly enjoyed the experience of communicating with everyone to gain a coherent idea of the project and translate that into text for the report."

Roger Lau, *R&D Officer & Engineer*, Class of 2017

"This being the first time I participated in the MATE ROV competition, I can gladly say that I've learnt a lot and gained many valuable experiences, from engineering to teamwork. Being able to apply physics and mathematics to real-life engineering was particularly rewarding, especially after overcoming many technical challenges along the way to produce the final product of *Die Meduse*. This competition has certainly raised my interest in the field of engineering and I will definitely continue to pursue my passion in the future."

Hain Yoon, *CAD Engineer & Safety Officer*, Class of 2016

"Joining the robotics team is evidently one of the most significant decisions that I have made this year. Not only have I accumulated valuable engineering skills and knowledge but I have also learned the importance of collaboration and communication within a group when developing such a project. Contributing in this project has allowed me to meet others who share the same level of passion and enthusiasm for physics, mathematics and engineering and has shaped me into becoming a more practical and methodical person in which I can overcome technical challenges in a more efficient and logical manner."

Matthew Zhang, *Engineer*, Class of 2016

"During the past 6 months of creating a ROV I have acquired many useful skills, especially the operation of the many tools that were used in its construction, and gained a lot of valuable knowledge, such as the application of physics and mathematics to engineering. I have also improved my ability to collaborate with others in many aspects of this activity. Overcoming the various obstacles throughout has challenged my creativity and perseverance. This has been a wonderfully beneficial and enjoyable experience."

Financial Report

Prior to incurring any expenses, we outlined a budget for the design, development and production of *Die Meduse*. In one of the first sessions, we assessed the funds we had available and from that developed a budget to guide us in distributing the $21500HKD we had at the beginning of the year (prior to receiving regional competition prize money). We were successful in staying within our budget spending only $2,571.99USD of our $2756.41USD spending budget. This was achieved through continuous review of our spending. Prize money from our regional competition was used to partially subsidize travel fees otherwise paid for by staff members.

Sources of Funding

Source	Amount in HKD	Amount in USD	Use
GSIS ROV budget	14,000.00	1,794.87	ROV
TÜV SÜD corporate sponsorship	7,500.00	961.54	ROV
Regional competition prize money	12,000.00	1,538.46	Travel
Total	33,500.00	4,294.87	

Budget

Expense	Amount in HKD	Amount in USD
Research and design (R&D)	7000.00	897.44
Chassis	1000.00	128.21
Tether	1500.00	192.31
Control box	1000.00	128.21
Control system	3000.00	384.62
Motors	3000.00	384.62
Cameras	1500.00	192.31
Payload tools	1000.00	128.21
Props for testing	500.00	64.10
Marketing display	1000.00	128.21
Delivery logistics	1000.00	128.21
Total	**21500.00**	**2756.41**

Travel Estimates

Expense	Amount in HKD	Amount in USD
Round-trip airfares from Hong Kong to St. John's	100,000	12820.5
Accommodation at Macpherson College, Memorial University	19,000	2435.9
Transport in St. John's	2,000	256.41
Food and beverage	4,000	512.821
Total	**125,000**	**16025.6**

The following pages detail our expenses log, kept updated by our Chief Financial Officer, Maxine Kwan. The date format is DD/MM/YY, the convention used in Hong Kong, our country of operation.

Expenses Log

Date	Item	Type	HKD	USD	Cumulative in USD
9/10/14	Acrylic Dome	Product Purchase	$71.50	$9.17	$9.17
9/15/14	PE Board	Product Purchase	$26.00	$3.33	$12.50
9/20/14	Shipping of PE Board	Logistics	$13.00	$1.67	$14.17
9/20/14	ESCs	Product Purchase	$345.80	$44.33	$58.50
9/20/14	Camera	Product Purchase	$143.00	$18.33	$76.83
9/25/14	Waterproof housing	Product Purchase	$188.50	$24.17	$101.00
9/27/14	Lasercut acrylic board	Paid Service	$40.00	$5.13	$106.13
9/27/14	Cables	Product Purchase	$184.50	$23.65	$129.78
9/29/14	Bilge pumps	Product Purchase	$179.40	$23.00	$152.78
9/30/14	Control box	Product Purchase	$257.92	$33.07	$185.85
9/30/14	Shipping of cameras	Logistics	$38.00	$4.87	$190.72
9/30/14	Shipping of cameras	Logistics	$30.00	$3.85	$194.57
9/30/14	Shipping of power clips	Logistics	$92.00	$11.79	$206.36
10/3/14	Epoxy	Product Purchase	$132.60	$17.00	$223.36
10/3/14	Shipping for buckle	Logistics	$30.00	$3.85	$227.21
10/3/14	Shipping for screws	Logistics	$30.00	$3.85	$231.05
10/4/14	Shipping for metal parts	Logistics	$38.00	$4.87	$235.93
10/4/14	Epoxy	Product Purchase	$392.00	$50.26	$286.18
10/11/14	Epoxy	Product Purchase	$255.00	$32.69	$318.87
10/11/14	Shipping for PE Board	Logistics	$30.00	$3.85	$322.72
10/11/14	Temperature sensor	Product Purchase	$30.00	$3.85	$326.57
10/27/14	Acrylic board	Product Purchase	$74.00	$9.49	$336.05
11/3/14	Nichrome wire	Product Purchase	$14.17	$1.82	$337.87
11/24/14	3D Printing of Thrusters	Paid Service	$182.00	$23.33	$361.20
11/25/14	Acrylic motor boards	Product Purchase	$104.00	$13.33	$374.54
12/2/14	Linear actuator	Product Purchase	$150.80	$19.33	$393.87
12/2/14	O-ball	Product Purchase	$53.30	$6.83	$400.70
12/6/14	Shipping of Cable	Logistics	$22.00	$2.82	$403.52
12/14/14	Linear actuator small	Product Purchase	$250.90	$32.17	$435.69

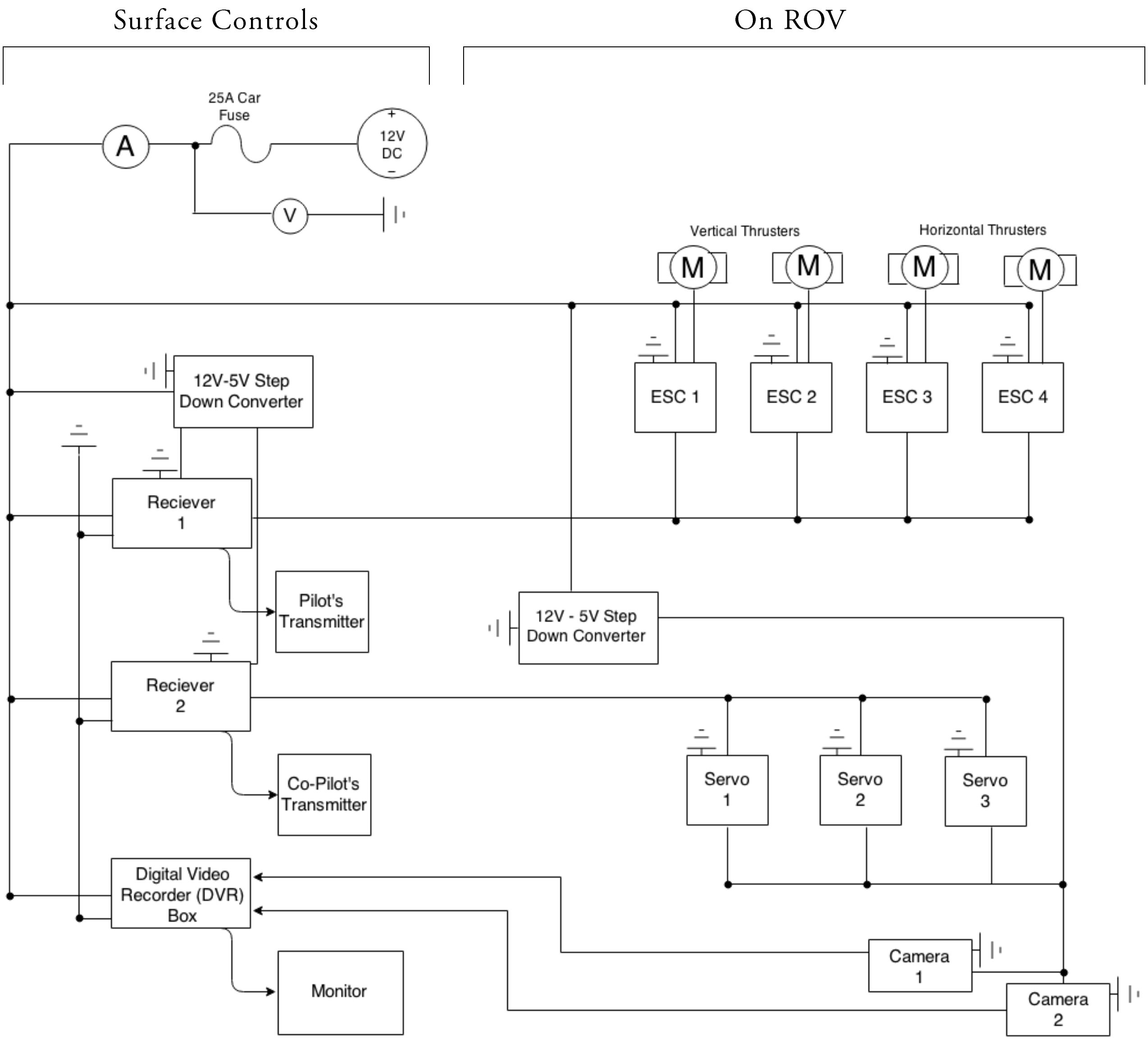
12/14/14	PP Board	Product Purchase	$91.00	$11.67	$447.36
12/22/14	10AWG Cable	Product Purchase	$439.40	$56.33	$503.69
12/23/14	Shipping of waterproof housing	Logistics	$30.00	$3.85	$507.54
12/27/14	Shipping of plexi glass	Logistics	$38.00	$4.87	$512.41
12/30/14	O-Rings	Product Purchase	$58.24	$7.47	$519.88
12/30/14	3D Motor	Product Purchase	$270.40	$34.67	$554.54
12/31/14	3D printing of thrusters	Paid Service	$364.00	$46.67	$601.21
12/31/14	Laser cut WTC lid	Paid Service	$143.00	$18.33	$619.54
12/31/14	Arduino distance sensor	Product Purchase	$68.90	$8.83	$628.38
1/2/15	Cable PET	Product Purchase	$111.80	$14.33	$642.71
1/10/15	Glass dome	Product Purchase	$57.20	$7.33	$650.04
1/10/15	Shipping for plugs	Logistics	$38.00	$4.87	$654.91
1/10/15	Cables	Product Purchase	$290.40	$37.23	$692.14
1/10/15	Waterproof Plug-ins	Product Purchase	$230.10	$29.50	$721.64
1/11/15	Security Camera	Product Purchase	$301.60	$38.67	$760.31
1/12/15	Acylic board	Product Purchase	$45.00	$5.77	$766.08
1/12/15	Cable components	Product Purchase	$236.50	$30.32	$796.40
1/14/15	Arduino components	Product Purchase	$78.00	$10.00	$806.40
1/14/15	Arduino components	Product Purchase	$130.10	$16.68	$823.08
1/15/15	Brushless Motor	Product Purchase	$522.60	$67.00	$890.08
1/15/15	Voltmeters	Product Purchase	$83.20	$10.67	$900.75
1/16/15	Lasercut chassis	Paid Service	$208.00	$26.67	$927.41
1/17/15	Glass dome	Product Purchase	$54.60	$7.00	$934.41
1/26/15	Cable Float	Product Purchase	$47.11	$6.04	$940.45
1/29/15	DC-DC Transformer	Product Purchase	$140.09	$17.96	$958.41
1/30/15	Lasercut acrylic board	Paid Service	$101.40	$13.00	$971.41
2/1/15	Lasercut polypropylene	Paid Service	$130.00	$16.67	$988.08
2/4/15	Lithium Batteries	Product Purchase	$258.54	$33.15	$1,021.23
2/8/15	Laser	Product Purchase	$212.81	$27.28	$1,048.51
2/11/15	Epoxy	Product Purchase	$153.40	$19.67	$1,068.18
2/11/15	Cable Float	Product Purchase	$18.72	$2.40	$1,070.58
2/28/15	Lasercut polypropylene	Paid Service	$448.50	$57.50	$1,128.08
2/28/15	Underwater Camera	Product Purchase	$126.10	$16.17	$1,144.24
2/28/15	Speaker Connection	Product Purchase	$134.16	$17.20	$1,161.44
2/28/15	Waterproof Servo	Product Purchase	$1,168.	$149.83	$1,311.28

			70		
3/6/15	Acrylic board	Product Purchase	$110.50	$14.17	$1,325.44
3/8/15	O-Rings	Product Purchase	$106.60	$13.67	$1,339.11
3/12/15	Underwater Laser	Product Purchase	$178.36	$22.87	$1,361.98
3/16/15	Acrylic board	Product Purchase	$52.00	$6.67	$1,368.64
3/22/15	Cable remote	Product Purchase	$313.30	$40.17	$1,408.81
3/22/15	Transformer components	Product Purchase	$108.67	$13.93	$1,422.74
3/24/15	Plexiglass tube	Product Purchase	$130.00	$16.67	$1,439.41
3/25/15	Speaker Transformer	Product Purchase	$98.15	$12.58	$1,451.99
3/28/15	Cable connectors	Product Purchase	$31.72	$4.07	$1,456.06
4/1/15	Underwater laser	Product Purchase	$130.00	$16.67	$1,472.73
4/1/15	Brushless Motor	Product Purchase	$338.00	$43.33	$1,516.06
4/1/15	Brushless motor	Product Purchase	$338.00	$43.33	$1,559.39
4/6/15	Lasercut polypropylene	Paid Service	$65.00	$8.33	$1,567.73
4/10/15	Electromagnet	Product Purchase	$182.00	$23.33	$1,591.06
4/10/15	Lasercut polypropylene	Paid Service	$136.50	$17.50	$1,608.56
4/11/15	USB DVR	Product Purchase	$214.50	$27.50	$1,636.06
4/15/15	Poster printing	Paid Service	$460.00	$58.97	$1,695.03
4/19/15	Camera	Product Purchase	$504.40	$64.67	$1,759.70
4/20/15	Cable mesh	Product Purchase	$147.68	$18.93	$1,778.63
4/21/15	Acrylic laser cut	Paid Service	$104.00	$13.33	$1,791.97
4/22/15	Cable	Product Purchase	$470.60	$60.33	$1,852.30
4/22/15	Blue Robotics T100 Thruster	Product Purchase	$2,519.40	$323.00	$2,175.30
4/30/15	Underwater camera	Product Purchase	$52.00	$6.67	$2,181.97
5/4/15	Waterproof plug-ins	Product Purchase	$272.74	$34.97	$2,216.93
5/4/15	Acrylic cut	Paid Service	$300.00	$38.46	$2,255.40
5/5/15	Underwater camera	Product Purchase	$214.89	$27.55	$2,282.95
5/5/15	CCTV Camera	Product Purchase	$712.40	$91.33	$2,374.28
5/7/15	CTi Cat5e cable	Product Purchase	$186.00	$23.85	$2,398.13
5/8/15	Lasercut polypropylene	Paid Service	$221.00	$28.33	$2,426.46
5/9/15	Underwater camera	Product Purchase	$384.80	$49.33	$2,475.79
5/14/15	Lasercut acrylic board	Paid Service	$54.60	$7.00	$2,482.79
5/14/15	Acrylic dome	Product Purchase	$76.25	$9.78	$2,492.57
5/14/15	Water-proof connectors	Product Purchase	$208.00	$26.67	$2,519.23

5/15/15	Underwater lenses	Product Purchase	$341.90	$43.83	$2,563.07
5/18/15	Acrylic dome	Product Purchase	$69.62	$8.93	**$2,571.99**

System Integration Diagram

The following is our system-level connection diagram. No pneumatics or hydraulics systems are used in our ROV system.



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Acknowledgements

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- Mr John Shearman, Head of Physics at GSIS for support and dedicating his time as mentor
- Dr Joachim Prinz, Deputy Principal and Chemistry Teacher at GSIS for helping with pool bookings and support
- Ms Petra Loho for media contacts

Competition Organizers

- Marine Advanced Technology Education (MATE)
- The Institution of Engineering and Technology (IET)