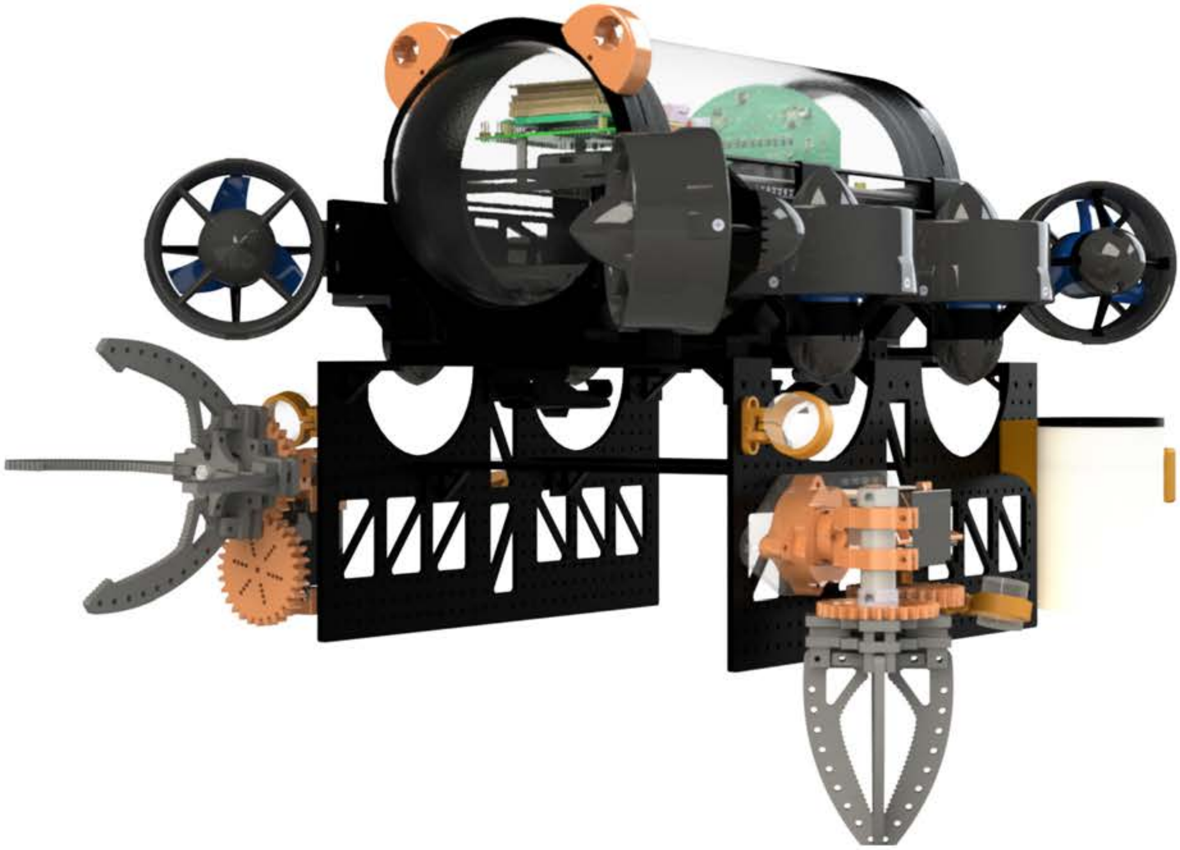
CITYU HK nderwaterrobotics

FRONTEER ROV

2023 MATE ROV TECHNICAL DOCUMENTATION



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ABSTRACT

Fig.1 CityU Underwater Robotics 2023

CityU Underwater Robotics ("CityU UR") consists of students passionate about underwater robotics. The company has developed a remotely operated underwater vehicle ("ROV") based on our engineering team's innovative ideas and professional knowledge. This ROV works greatly to fight against climate change, preserve the marine environment and shape a better future ocean environment.

As the culmination of previous experiences and countless experimentations, our team has further refined the design of Fronteer. The past experiences widened our horizons in developing both mechanical and electronic designs. A brand new gripper design was first introduced as a part of major changes this year. Apart from the gripper, our team deployed an enhanced electronic system to Fronteer including a motherboard with a compact design, an advanced daughterboard system and a new power module. These changes to Fronteer address numerous performance-related issues found in the previous sessions, bring extra room for further refinements and enhance flexibility, mobility and stability. In addition, a new stereo camera was deployed to enhance Fronteer's capability for performing automated tasks. Additional parts designed were manufactured and used with our mature in-house 3D-printing technology.

The following technical documentation presents the design rationale including all designs mentioned above as well as the development and management process during the evolution of Fronteer.

2.1 Design Process

Understanding the task
All our engineers shall fully understand the specifications to ensure our design fulfils the task requirement.

Brainstorming
To find out the simplest way to complete the tasks, we encouraged all engineers, including junior and senior, with various technical backgrounds to propose their creative ideas, even if some may need to be more practical. Some surprising and innovative elements could be implemented into our design during this stage. All engineers stayed together and were fully involved in this stage. Designing Our designers created the first draft on paper. They explained their design rationale, for instance, the working principles, to senior engineers in detail on the whiteboard. Our engineers would provide feedback as peer review. This practice ensures that our design is both innovative and feasible through collaboration.

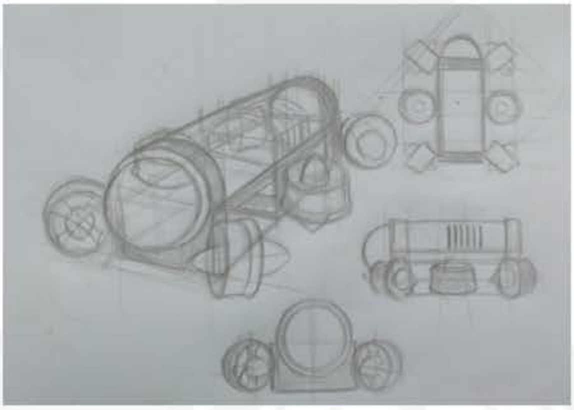

Fig.2 Hand sketch of Fronteer at Brainstorming Stage

Prototyping
To facilitate the prototyping, we created a CAD model with SolidWorks, which could be used in 3D printing and simulation in the following stage. 3D printing provided an efficient way for our engineers to create a functional prototype at a low cost.

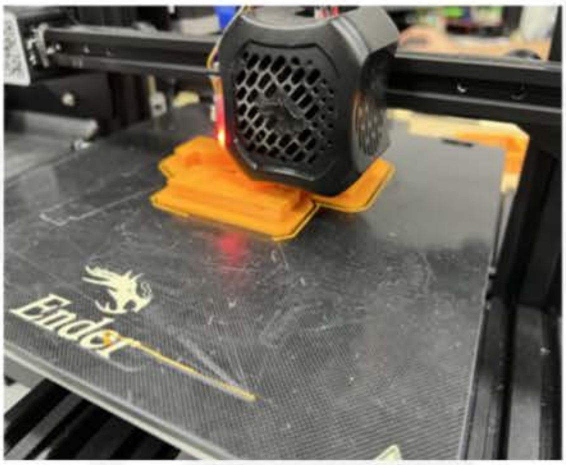

Fig.3 3D Printing Prototype of Camera Mount

Testing
The design was verified by computer simulation modelling. SolidWorks had various simulation functions, for instance, fluid dynamic modelling. The simulations allowed our engineers to undergo an in-depth analysis of the physical properties of the design. Our engineers could amend the design with professional knowledge and make it more reliable according to the simulations. The results would also be compared with the physical testing.

Modifying
The design was modified according to the pivot satisfaction, opinions of senior engineers and previous test data. The final design had gone through iterations of the design modification loop to ensure it could complete the tasks effectively and efficiently.

Design Rationale

2.2 Mechanical

Design evolution

Enhancing Fronteer's performance and functionality has always been a top priority for our team. By analyzing the previous performance of Fronteer concerning the manipulators, improving the flexibility of aiming and gripper controlling are considered the major task of the mechanical team. Hence, we introduce our new own system-oriented and task-oriented designs which are a rotatable gripper with a better gripping mechanism and our pioneering Quick Angular Adjustor instead of outsourcing other products in the market.

Frame and structure

Taking into account lessons learned from prior years, the frame has been modularized to support various missions as well as reduce design time. Figure 4 shows how to customize the 6061 Aluminum frame into either the compact or extended form by connecting or detaching the bottom payload rack, as shown in Table 1. Lightweight carbon fiber rods are used for the grasp point to reduce transportation difficulty.

Year	Compact Frame	Extended Frame
Dimension (cm)	45 x 37.3 x 19	53.8 x 37.9 x 27.6
Weight (kg)	9	12

Table 1: Comparison of Compact and Extended Frame

Despite its weight and cost, the 6061 Aluminum alloy is preferred as it enables mounting additional components without screw nuts to strengthen the frame, reducing both assembly time and the need for unnecessary components, thanks to the frame's uniformly spaced threaded holes to minimise transportation difficulty.

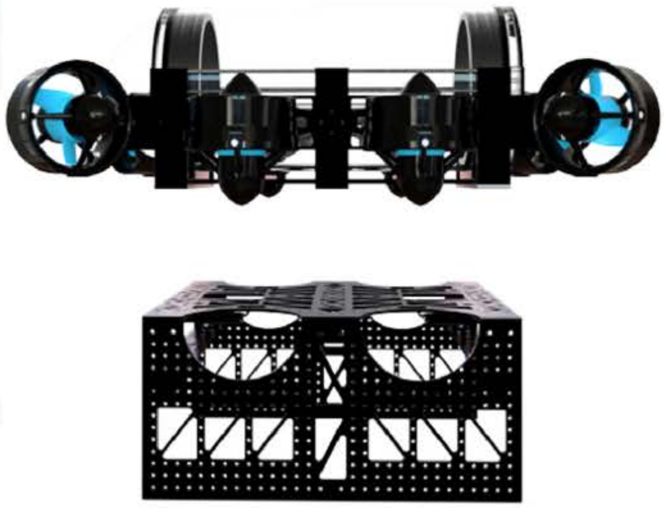

Fig.4 Exploded View of Side Frame

Design Rationale

Fig. 5 Exploded View of Container

Fig.6 T200 Thruster

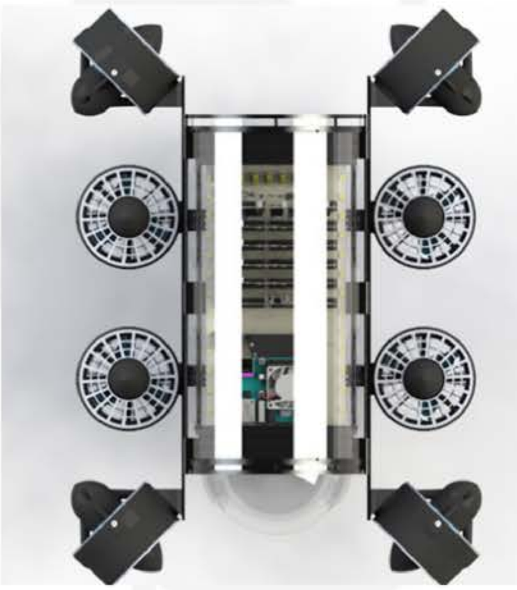

Fig.7 Thruster Configuration

Electronic tube

The electronic housing is sealed inside the acrylic tube using CNC Aluminum flanges with double O-rings and double aluminium plates, acrylic plates, and spherical caps at both ends. During assembly, the O-rings are pressed against sealing parts to waterproof the tube.

The electronic housing rack is mounted using four standardized steel studs for their strength and thread. Two carbon fiber end plates direct the stud head to the corresponding thread hole of the flange. The rack features two levels of slots, one for the motherboard and the other for daughter board placement on a carbon fiber plate.

Propulsion

The propulsion system comprises eight Blue Robotics T200 arranged in a vector configuration to achieve 6-DoF. Four T200 motors control Sway, Surge and Yaw, while the others control Roll, Pitch and Heave. With the autopilot system, the vehicle could have complete control over its pose.

Buoyancy

Since Fronteer has adopted an electronics tube design to store all electronics, the large volume of air from the tube provides positive buoyancy.

Hence, flexible buoyancy adjustment is necessary due to the vehicle's multiple add-on components. Polyurethane foam and lead weights can adjust buoyancy positively or negatively. PU foam was chosen for its low water absorption rate, high resistance to compression, and ease of shape adjustment for maintenance and fine-tuning. At the same time, lead weight has a higher density and takes up less space, allowing for a sleeker vehicle design.

Pneumatic system

Fronteer uses a pneumatic system regulated to 40 psi (2.65 bar) as a reliable power source for specific manipulators. Appendix B contains the System Interconnection Diagram of the Pneumatic System.

2.3 Electronics

Design Evolution

New components and boards have been introduced in the electronic part to operate the rotatory gripper system and new Single Board Computer (SBC) features. The new daughter board communicates between the SBC and manipulators, allowing the pilot to control the angle and operation. The board also controls LED brightness without any flicking issues. Moreover, a power board is included for SBC power.

Protocol Update

This year we introduced the CAN bus protocol to centralize all the communication between slot cards. It allows much more flexibility as message IDs are defined on the software side so Nodes can be added dynamically. The CAN bus will be converted to a UART signal before communicating with the SBC.

Manipulator Board

The manipulator board receives commands from the SBC via the UART bus on the motherboard and controls the manipulator, including pneumatic, servo, searchlight, etc. This new version of the manipulator board redesigned and simplified the circuit controlling the pneumatic valves to allocate fewer MCU resources and physical space to perform the same task.

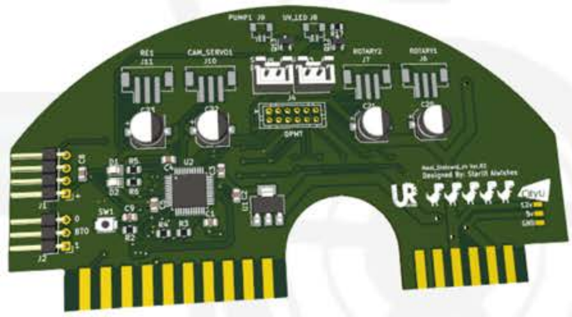

Fig. 8 Rendered Manipulator daughter board

Camera and Peripheral Daughter Board

The Camera and Peripheral Daughter Board are to route video outputs to distinct signal channels. It could provide well-ordered video outputs for the pilot. To fully utilize the camera, a servo motor controls the camera's rotation, and an onboard step-down voltage regulator converts 5V from 12V for the servo motor.

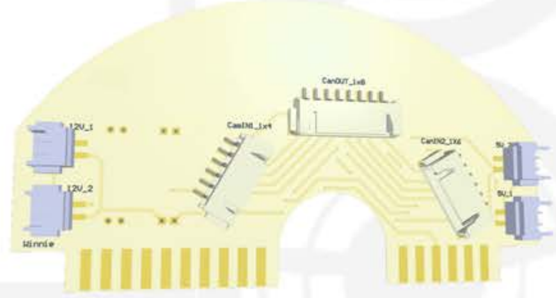

Fig. 9 Rendered Camera daughter board

Debug Board

The Debug Daughter Board is used to speed up hardware diagnosis of the backplane by providing visual indications and test holes around the edge of the card. These holes are connected to the power, signal, and thruster control buses. Engineers can directly connect a logic analyzer or oscilloscope to the test holes in case of any error. Alternatively, measurements from various buses can be viewed from other devices via Bluetooth. Such design allows engineers to understand the status of the vehicle without the need to open the electronic tube.

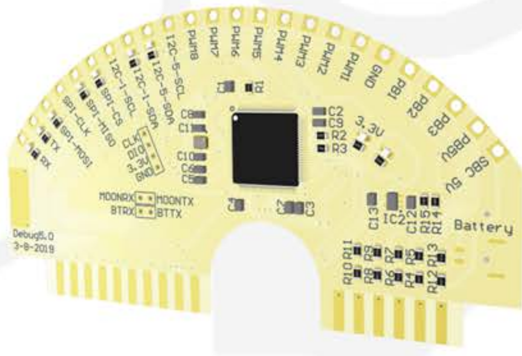

Fig. 10 Rendered Debug Baord

Design Rationale

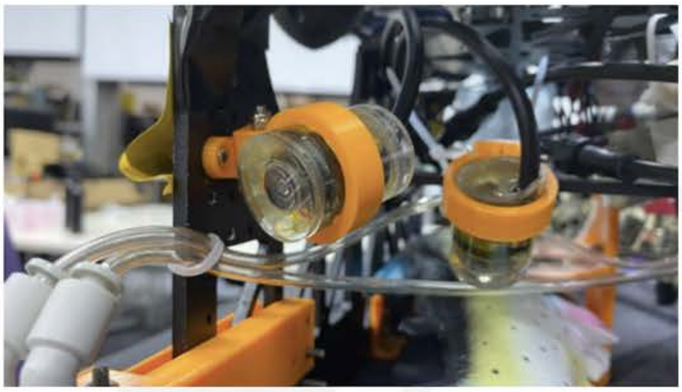

Fig.11 Analog cameras positioned on frame

Vision

Six auxiliary cameras were installed onto the Fronteer, including one digital camera, one stereo camera, and four analog cameras to provide different view angles for the pilot to complete underwater tasks. Both digital and stereo cameras can change the viewing angle, allowing the pilot to search for objects at different heights. The digital camera is inside the main electronics compartment, whereas the other cameras are outside. In contrast, the 4 four analog cameras are task-specific cameras that aim to focus on the manipulators, and the stereo camera is mainly for doing computer vision tasks.

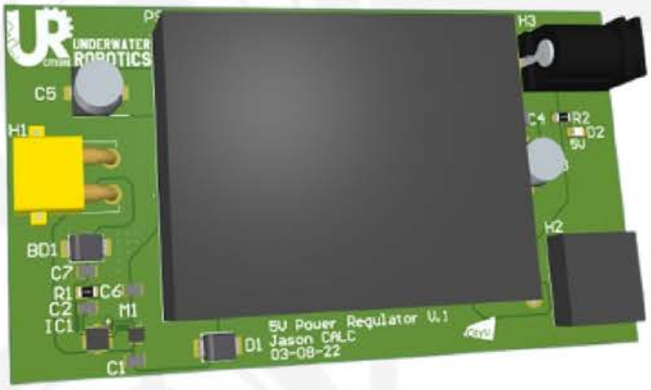

Fig. 12 Rendered SBC power converter

Power

An additional power converter is used to power the Jetson Nano system in the ROV. The new power converter will convert the system power into the 5V output for the Jetsosn Nano. To provide safety features for the ROV, the input side of the power converter will consist of a safety IC circuit to prevent short-circuit, reverse voltage, and current and overvoltage problems. Moreover, the board will also provide an auto-recover feature, which the circuit will recover from the short-circuit incident.

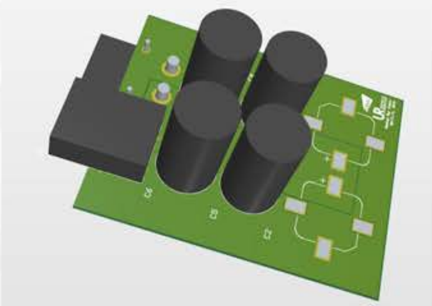

Fig. 13 Rendered capacitor board

Capacitor Board

A new version of the capacitor board is designed with fewer capacitors by default. It contains two capacitors with an enormous ripple current of around 20A, while the other two have a large capacitance of up to 2200uF. Both of these capacitors can stand 63VDC. There will be spare spaces to install more capacitors if the default setup is insufficient.

2.4 Software

Computer Vision

i. Underwater Photogrammetry

Fronteer is equipped with a ZED Mini stereo camera, and the images captured from this camera are transferred to the software installed in the topside computer, where a 3D photogrammetry algorithm will be applied on various objects, reconstructing a 3-dimensional mesh of the objects with high-fidelity textures as well as obtaining their dimensions with error threshold within 2cm.

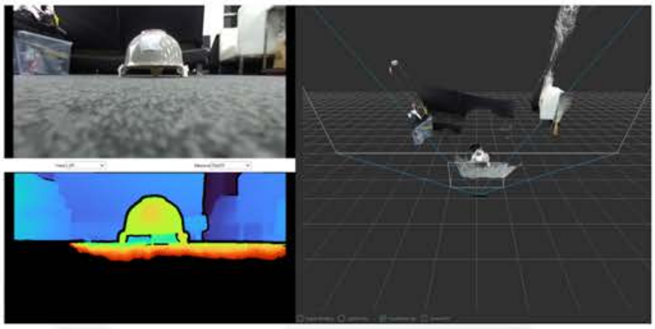
Fig. 14 Overview of 3D photogrammetry application

ii. Autonomous Docking

Fronteer can dock into the station autonomously. Implementing the computer vision algorithm and using OpenCV to extract information from camera input. Once the red button is found, the centre coordinates will be reported to the motion controller for the autonomous docking process.

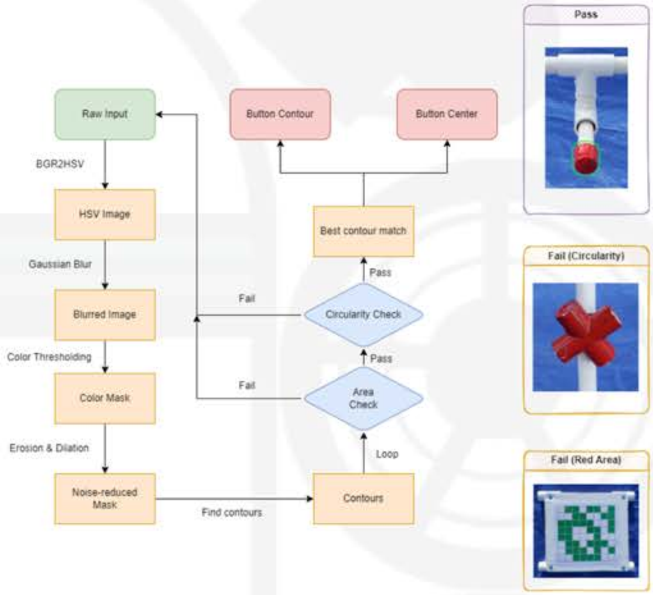

Fig. 15 Flow chart of Button detection algorithm

iii. Seagrass detection

Fronteer designed the algorithm to autonomously compare the old three months prior seagrass visual data with the current image captured by the ROV. The camera will capture the old data at the ground station, and the difference count will then be displayed in the GUI.

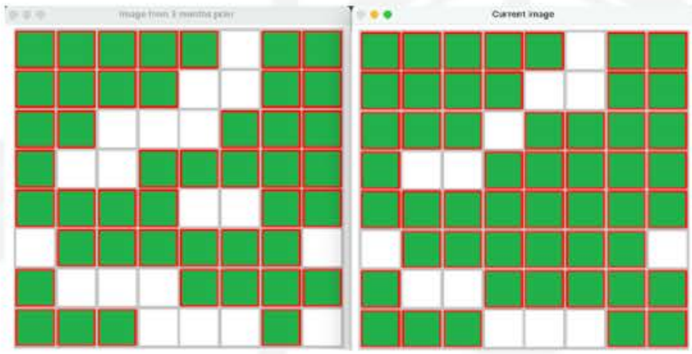
Fig.16 Example result of Seagrass detection

Underwater Simulation

A standalone simulator is developed to train machine-learning-based Computer Vision algorithms with greater efficiency to provide virtual images without accessing water in reality. Empowered by Unity HDPR, the simulator renders the virtual environment with photorealistic effects. Objects in the simulator are created by CAD software and Blender for scene generation. A GUI is developed for this standalone system to enhance user experience and provide scene customization. As a result of implementing the simulator, our team could train and test the CV algorithms under normal and extra conditions at any time.

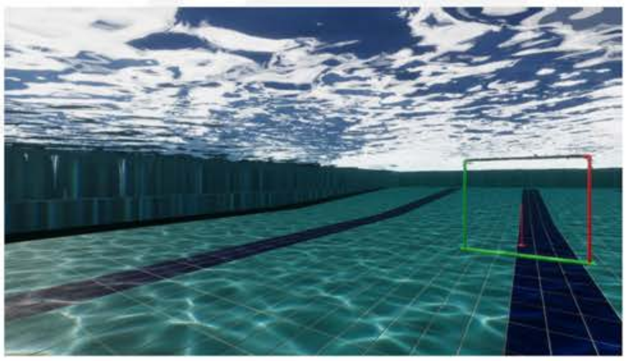
Fig.17 Underwater simulation graphic

Fig. 18 GUI design used in ground station

The graphical user interface (GUI)

The GUI provides the communication interface between the pilot and the robot. The design of GUI is intuitive to let the pilot monitor and control the current status of the robot. The GUI is created with a plugin design using Rqt and connected to ROS. The GUI can monitor and display messages from other nodes in the network and send signals to nodes responsible for controlling the robot components. As a result, the GUI provided a complete and smooth operating experience for the pilot.

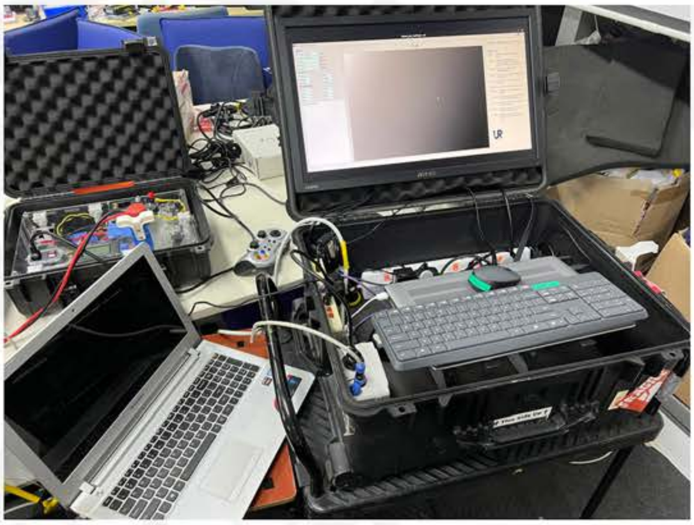

Fig. 19 Ground station of **Fronteer**

2.5 Control station

In previous generations of Fronteer, the control station consisted of a modified pelican container to house various components, including the control station computer, router, powerline communication module, and controlling device. A laptop equipped with a dedicated Graphic Processing Unit is used in the control station, resulting in a much lighter overall weight, more straightforward setup, and more flexible configuration in the field.

Software on the control station has also undergone an overhaul. Pilots now have a foolproof method of opening the entire control interface with a one-key startup script and completely repackaged ROS.

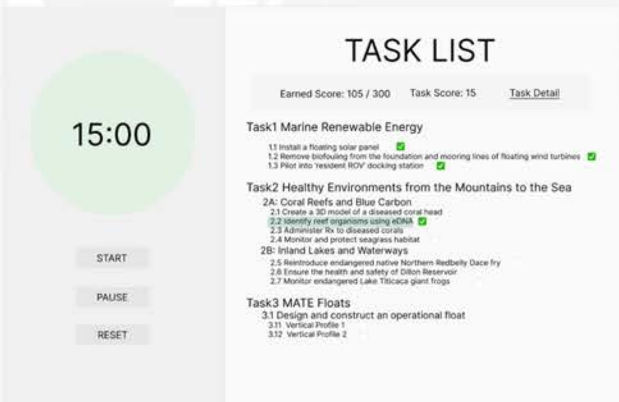

Fig. 20 Mission planner interface

2.6 Mission planner

The Task Manager is a web-based application designed to assist pilots in managing their tasks during competitions. With this manager, the co-pilot can easily modify the task-finishing order. Tasks are categorized as to-do, in progress, or completed and can be sorted or filtered based on various criteria. A timer and integrated manual viewer are also embedded in the manager.

Mission-specific tools

To complete tasks requested by the UN DECADE OF THE OCEAN, Fronteer is equipped with customized tools.

2.7 Mission specific tools

Gripper

A 4-jaw gripper is designed to handle all objects. Two grippers are installed on the left and right sides of the rack, with one facing front and the other facing downwards. The grippers feature a rotary mechanism using bearings, servo motors and gears to improve flexibility and enable Eco-Mooring installation.
The assembly comprises laser-cut sheet metal parts controlled by a pneumatic cylinder, and the four sawed jaws increase friction to prevent the object from slipping during ROV movement.

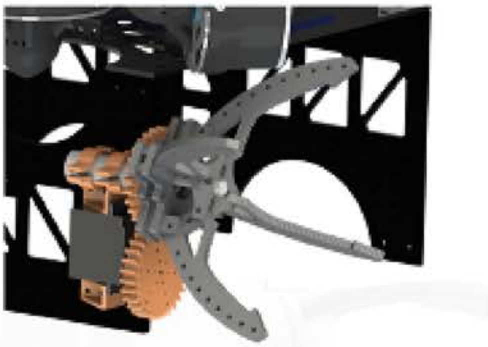

Fig.21 Rendered Frontward gripper

Fig. 22 Rendered Downward gripper

Quick Angular Adjuster

The Quick Angular Adjustor comprises a mount, piston, and spring. The mount is permanently attached to the ROV and features a circle hole inside and a square hole outside. With the spring pushing the piston outwards, the square-shaped piston will be locked inside the square hole of the mount. By pressing the piston, it can be pushed into the circle hole, allowing adjustment of the gripper angle to 90°/180°/270° offset. Releasing the piston locks the gripper angle in place with the square hole of the mount. As requested by the pilot, we can change the square hole to other regular polygons to achieve more angle adjustment.

Fig. 23 Rendered Two views of UV light source

Light source

The UV light source has a diseased area cover made of a PVC tube and black acrylic board to block external light and cover the affected area. The illuminant consists of four green LEDs with a 540nm wavelength illuminating the photoresistor.

Water sample extractor

The Water sample extractor uses a peristaltic pump to prevent water flow into the containers when not powered on due to high water pressure. A stainless steel straw is a penetrator to cut through cling wrap.

Fig. 24 Water sample extractor

Fig. 25 Rendered Searchlights

Fig. 26 Rendered Camera mount

Fig. 27 Rendered Buoyancy Engine(Front view)

Fig. 28 Rendered Buoyancy Engine(side view)

Searchlights

Two searchlights are installed on Fronteer to enhance the performance of the computer vision algorithm by increasing the brightness and clarity of the image captured underwater.

Camera mount

The camera mount comprises a top camera mount, middle pit angle mount, and bottom yaw angle mount. The two-angle mount has a hexagonal pit for secure angle placement. The screw adjusts the ease of camera angle movement, allowing for a 180-degree view. The angle of view can be easily adjusted by hand, and the hexagonal pit holds the angle in place.

Buoyancy Engine

The buoyancy engine is built with two watertight enclosures and external mounting supports. These two watertight enclosure kits are assembled by PMMA tubes and Aluminum alloy flanges.

The upper part, the electrical enclosure, includes one 2.4GHz antenna and a circuit board to collect data from the pressure sensor and control the peristaltic pump. Two 9V batteries power the whole system.

The enclosure on the bottom is mainly used for adjusting the buoyancy by controlling the water volume inside. A pressure sensor is used in the machine to indicate the engine's position. The engine could self-identify its position by calculating the fluid pressure and depth.

Bluetooth would be used to transmit and receive data to communicate between the ground station and the engine. The master-slave mode would be set up in the Bluetooth modules to avoid improper connection. They are only allowed to be paired with each other and keep requiring re-pairing if they disconnect. A 2.4GHz antenna would increase the signal strength to guarantee data transmission.

To prevent electrical shock, the battery mount is designed to fix the position of the batteries onto the PCB. And the customized PCB would be mounted onto the upper aluminium alloy flange.

Design Rationale

Fry Release Container

The Fry Release Container transports fry to a safe release area, allowing them to acclimate to local conditions. It contains an electronic module that counts down the time needed for adaptation and controls the opening of the container using an electromagnet. The lid is attracted to a copper plate, and once the countdown is complete, the electromagnet releases it, and the fry is released in the designated area. The electronic module is stored in a watertight enclosure, and the fry container is covered with a lid. The electromagnet is placed near the lid to attract it.

Fig. 29 Rendered Fry Release Container

Lift Bag

A lift bag is used to lift heavy containers as the ROV has limited lift capability. The bag is inflated by pulling the handle, which breaks a hole in the carbon dioxide trachea. A string is connected to the handle to the ROV for pulling, and a hook is used to connect to the U-bolt of the container.

Fig. 30 Lift bag

Stereo camera

Fronteer is equipped with a ZED Mini stereo camera, which features dual high-speed 2K image sensors, each with a 110-degree field of view, all in a small-size form factor that weighs only 60 grams.

A custom waterproof acrylic container is designed and fabricated in-house to enable its usage in underwater settings. A waterproof servo is attached to the container, allowing the pilot to adjust the camera's angle. The image feed is transferred to the control station via an extended cable that is attached to the main tether.

SAFEY

Safety Philosophy

Safety is prioritised in CityUUR. Our company considers the safety and health issues of our fellow members in every task we have done. Fronteer is a well-design vehicle which fulfil safety requirements and standards. In such a way, it could minimise the risks of injury to our members during operation as well as the logistics of the vehicle.

Creating a safe working environment for our fellow members is critical as well. Our company designed different safety protocols for our members. They need to adopt suitable protocols under different situations, like constructing ROV or during the operation of ROV.

Safety

Safety Feature of ROV

Our mechanical engineers ensured that ***Fronteer*** is safe to handle by adopting various safety features to minimize risks to the crew and threats to the environment during its operation:

- All moving parts and hazardous components are **labelled with eye-catching labels** which are noticeable to any users.
- **No sharp edges** are exposed during the main frame construction and other hardware components' manufacturing.
- The **propellers are protected with shrouds**, which protect users from cutting injuries caused by propeller blades.
- A **kill box**, containing a fuse and a kill switch, can shut off the system immediately in case of emergency or any abnormal operation situation.

Apart from hardware safety measures, our software engineers also developed several systems to monitor ***Fronteer's*** status to prevent any unstable situation:

i. **Fail-safe system**, which recalls the ***Fronteer*** to surface once the connection is closed. The measure could prevent the loss of vehicle during its expedition. A signal would be sent to the onboard LED strip which indicates the vehicle's status in patterns and colors, for instance, 'Power On', 'Bug Detected', 'Performing Mission' or even 'High Current'. The pilot could decide according to the status shown.

Fig.31 Backplane with Fail safe system and LED Display

ii. **Management Unit with a power sensing system and overcurrent protection** is used to trace the current performance of the system and provide protection over overcurrent, short-circuits, overvoltage and transient voltage. In case of emergency, ECPO can be activated in two modes depending on the situation to cut off power to the thruster only or the whole vehicle.

Operation Safety Protocol

Our operators are required to fill in a safety operation checklist (attached in Appendix C) before, during and after any operations. With this standardized procedure, operators could check the functions and status of ROV, which protects them from potential risks or injuries.

Safety

Lab Safety Protocol

CityUUR organizes compulsory lab training sessions every year for new members to familiar- ize with workplace safety and lab practice. Each training session consists of two hours. Senior engineers would demonstrate safety measures, including usage of personal protec- tive equipment (PPE), proper machine usage and emergency training. Peer evaluation will be conducted during training session, to recognize the safety of ourselves and other's. In such practice, each member understands safety measures at workplace, which truly prioritiz- es 'safety' as the core value of our company.

To ensure a safety working environment, a Job Safety Analysis (JSA) form and PPE are required for member to review and use before performing any heavy machinery, to minimize the potential risks and threats to members.

Fig. 32 Peer Training System when performing heavy machinery

LOGISTICS

Project Schedule

At the beginning of the new season, the CEO and department leads confirms the approximate schedule of all events throughout the entire academic year, including training for new members, design and prototyping, testing and modification, and finally report writing. This helps the team to understand the expected deadline of their tasks. Detailed deadlines are confirmed once the competition details are released.

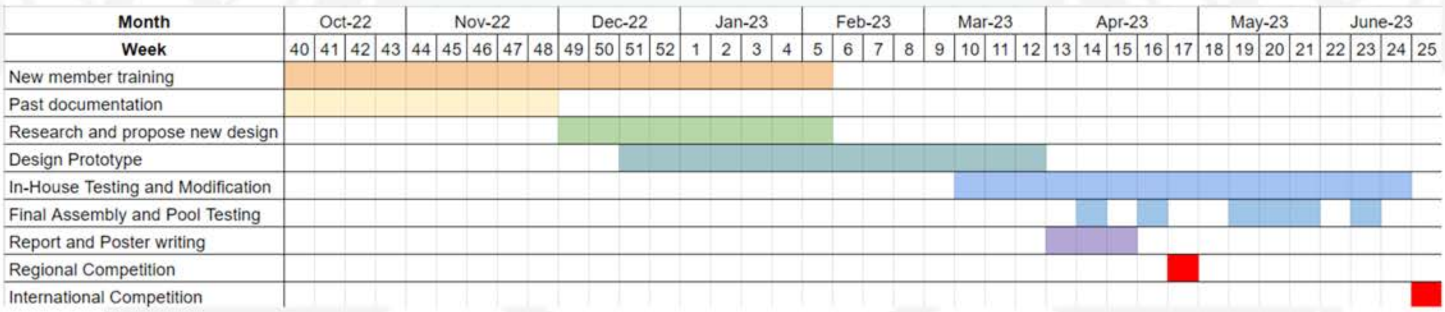

Table 2: Work Schedule of **Fronteer**

Logistics

Company Structure

CItyUUR is divided into four departments, namely Mechanical (ME), Electronics (EE), Software (CE) and Public Relation (PR). This simple but effective organization structure ensures sufficient autonomy for each sub-team when it comes to design decisions, while sustaining efficient communication between the project manager and each sub-teams.

Each member is assigned to different departments according to their technical background and strengths. Each department has an engineer lead, who keep track of the project progress and ensures proper division of labor. The project is supervised by a project manager, who monitors the each department's progress towards the goal, delegation of responsibility, budget and spending. The CEO oversees the whole project and give a proper direction for the company

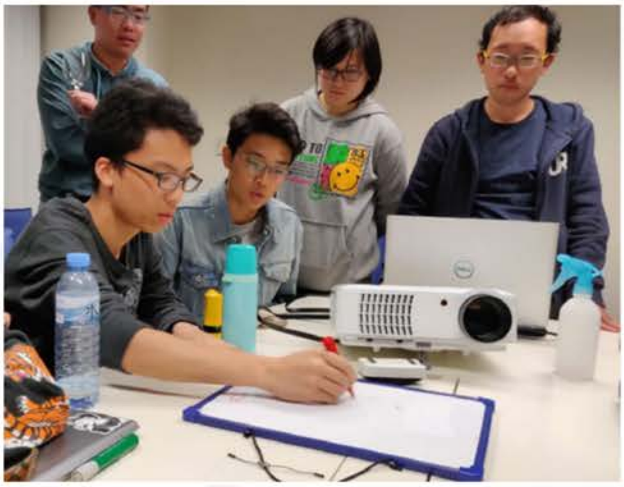

Fig.33 Idea brainstorming during weekly meeting

Management Platform

CityUUR utilizes tools such as Google Drive and self-hosted Git server to facilitate file storage and proper code management. These tools have been instated in the company a number of years ago, and they have proved essential to our daily work.

This year, CityUUR introduced new management and productivity tools for the company members to enhance the task-tracking and documentation experience.

ClickUp is used as the universal task-tracking platform for all members. It features a cross-platform user interface, allowing our company members to record and document their work progress clearly and in a easily visualizable manner. It has been very helpful for all the members to report their progress promptly, and even more helpful for the department leads, the project manager and the CEO to monitor the progress. Design decision and prototype iteration are clearly recorded as well, providing a comprehensive history of development of each component as well as a much easier time to backtrack in case any error is found in the prototypes.

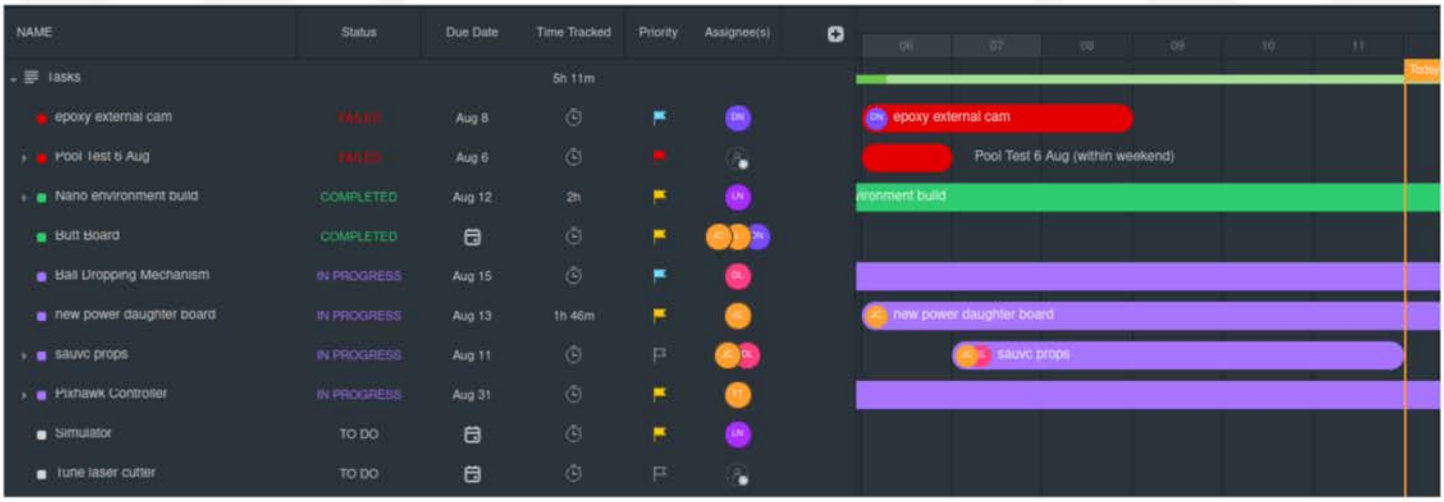

Fig. 34 ClickUp task interface

Logistics

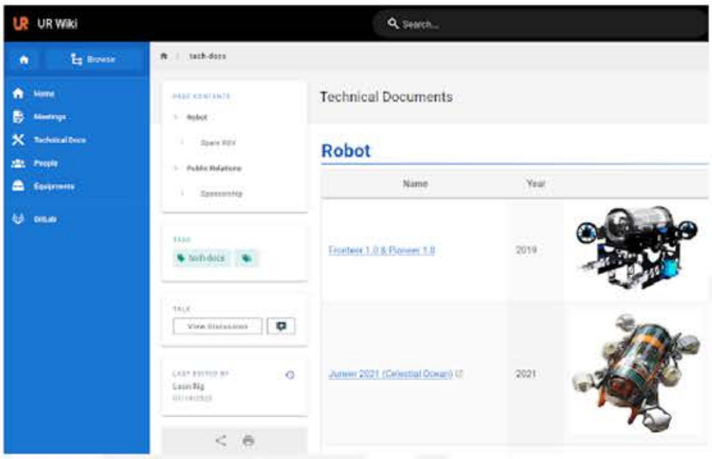

Fig.35 Idea brainstorming during weekly meeting

HackMD and Wiki.js is set up for team members to quickly access meeting notes and technical documents for each machine. As seen in the project schedule section, the company has dedicated a considerable portion of time towards documenting the legacy machines that the company has built in the past. This is due to members finding out that there has been great difficulty to understand or find out the process that lead to design decision on some of the components of previous generations, as well as some of the critical Standard of Procedures (SOP) and datasheets. By storing all textual records of meeting and confirmed specification of components, HackMD and Wiki.js proved an essential tool for quick lookup of internal technical information.

Project Budget and Expense

Fronteer's budget is set at the beginning of the year and estimated according to the previous project, which covers the cost of ROV construction, the MATE Competition, and the team's daily operation. This year, the major expenses are pool rental and electronic system costs.

With limited resources, financial planning and monitoring are essential. Each department has a strict budget to follow, and all the purchases will have to be reviewed and approved by the department head. Receipts will be recorded in the monthly expenditure list for tracking purposes.

CityUUR 22-23 Budget Breakdown

Category		Items	Quantity	Unit Price	Total (HKD)	Remarks
R&D Project	Cosumable	BlueRobotics T200 Thruster	5	1800	9000	
		ROVMaker Thruster	6	600	3600	
		Tether	30	60	1800	60HKD @ 1m
		ESC	5	550	2750	
		Watertight Enclosure	4	325	1300	
		Waterproof Penatrator	80	30	2400	
		Waterproof Plug	80	25	2000	
		Waterproof Cable	65	20	1300	10HKD @ 1m
		CNC Custom Frame	3	5000	15000	
		3D Printing Filament	10	500	5000	
		Mechanic Hardware	1000	2	2000	Bolt, Nut
		Floatation Foam	10	100	1000	
		Custom PCB	25	100	2500	
		Passive Electronics Component	20	100	2000	
		Single Board Computer	4	700	2800	
		Coral USB acclecrator	2	500	1000	
		Microcontroller	100	18	1800	
		Connector	500	5	2500	
		Battery	5	700	3500	
		Waterproof Strobe Light	4	300	1200	
		USB Camera	4	1000	4000	For computer vision
		Motor	6	375	2250	
				Total Amount for Consumable	**70700**	
	Training	Electronics Kit Set	20	100	2000	For mini robot
		Mechanical Kit Set	20	200	4000	For mini robot
				Total Amount for Training	**6000**	
	Pool Testing	Pool Rent	15	2000	30000	
		Transportation	15	120	1800	
				Total Amount for Pool Testing	**31800**	
	Equipment	Logic Analyzer	1	4500	4500	
		Power Supply	2	3000	6000	
				Total Amount for Equipment	**10500**	
				Total Amount for R&D Project	**119000**	
Competition Expense	SAUVC Singapore	Air Ticket	16	4250	68000	
		Catering	16	990	15840	
		Hotel	16	4100	65600	
		Transportation	16	400	6400	
		Insurance	16	260	4160	
				Total Amount for SAUVC	**160000**	
	MATE ROV USA	Air Ticket	14	13000	182000	
		Hotel	14	3000	42000	
		Catering	14	700	9800	
		Transportation	14	500	7000	
		Insurance	14	350	4900	
		Robot Shipping Container	1	2300	2300	
		Robot Shipping Fee	2	10000	20000	
		Competition Registration Fee	1	2000	2000	
				Total Amount for MATE ROV	**270000**	
	Total Amount for Competition Expense				**430000**	

Table 3: Project costing and budget

Testing & Troubleshooting

Testing is a critical stage that verifies our ideas and design through practice. Objec- tive analysis and prototype comparison are needed for evaluation and decision-making.

We built a few prototypes based on different designs or ideas and went through different testing. In the beginning, we tested each component independently to check their performance. This individual testing allows us to understand better each component's functionality and stability, which is critical in system design. We also utilized different simulation tools, for instance, the Gazebo simulator and SolidWorks. The SolidWorks can simulate and check the hardware functionality, while the Gazebo simulator can test the vehicle's software. Trying simulation tools can save time and money compared to constructing accurate models. They can output reliable results with minimum effort.

However, some errors in simulation may not be preventable, such as the roundoff and truncation errors. Therefore, pool tests are needed to determine the performance and practicality of the ideas and design of our vehicle. Parameters, including stability, efficiency, buoyancy, manipulation and overall performance, are considered in the pool test.

A systematic and logical flow is created for tackling the problems based on a trial-and-error approach while fulfilling the safety requirement. The following figure shows our troubleshooting approach.

Fig.36 Approach of troubleshooting

Due to various undesirable factors, the vehicle may need to meet our expectations during testing. Therefore, we simulated the scenario several times to identify those factors. Then, we referred to the original concepts and fundamental theories to eliminate those undesirable factors. Next, we conducted tests again to check the validation of suspicion. Finally, we modified the design by altering the structure.

Challenges

Technical

This year we have built our first modular backplane, which integrated every sub-system. In such a high-density environment, noise reduction and thermal performance is the biggest challenge this year. One solution to reduce noise is to separate the power and signal on the PCB design. As such, our electronic engineers have done a series of PCB iterations for different hardware isolation methods to lower the noise level, which our engineer has successfully reduced to an acceptable level.

However, our engineer observed that the heat generated from the power system and external heat sources caused some 3D printed parts in the Electronic Housing to melt when the vehicle is placed under the sun for an extended period. Different cooling methods have been tried to prevent overheating, but the best solution is yet to be found. To ensure the system remains stable under high temperatures, an oven test has been done on all our PCB to ensure it can remind functional at 100 °C for 30 minutes.

Conclusion

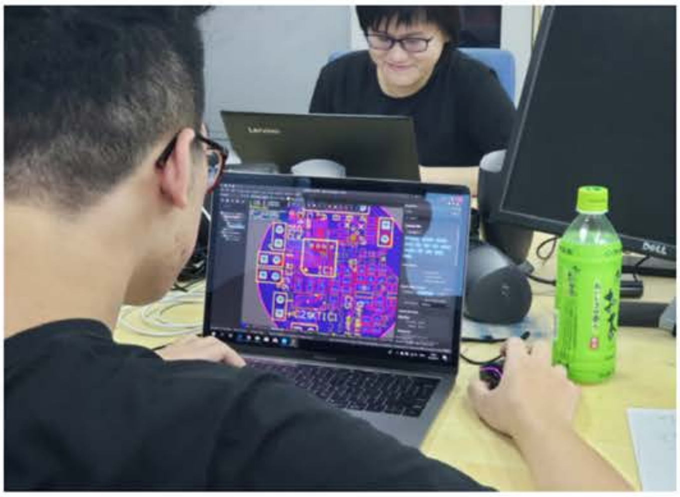

Fig.37 Electronic Engineer drawing PCB

Fig.38 Iteration of PCB

Non Technical

CityUUR is an organization which consists of more than 30 members. Team management is always one of the challenges such as communication and labour division. By using various platforms mentioned, such as Google Drive, information flow can be maintained. Members can access the most updated files and work on the files simultaneously for better collaboration. Freedcamp can set up schedules for members to follow, ensure the progress of the project is on track as well as even the workload for each member.

Resources, including money, is another challenge in this project. With a limited budget, purchases of some components may be off-schedule due to insufficient cash flow, which slows the project's progress. Having good financial planning is one of the solutions. Items are purchased according to their priority, based on current cash flow and availability of the product. Fundraising will be an alternative. Our company looks for sponsorship and donations by organizing different activities such as workshops

Lessons learned and skills gained

Technical Lesson Learned

As mentioned earlier, a modular electronic system was used this year, all peripheral system has been integrated into the daughter board and the main system has been integrated into the backplane. This system was built based on one master template, whereas other circuits are developed following this. Our engineer realizes that the master template is very beneficial to the whole workflow and eases a lot of processes since it allows an engineer who is less familiar with the whole electronic system to be able to work on a particular sub-system. Extensive simulations are also conducted throughout the mechanical design process on the manipulator and frames, to testify the design before manufacture.

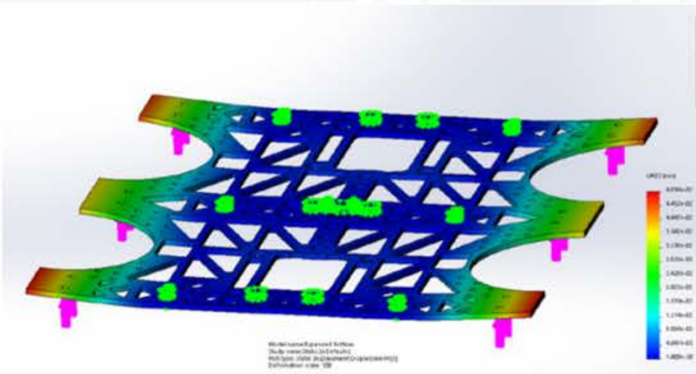

Fig.39 Stress Test on Side Frame

Conclusion

Interpersonal Lesson Learned

Each year, new engineers are recruited into the company as Juneer team. Bridging the gap between junior and senior members is often hard as they are unfamiliar with a new environment with different cultures and backgrounds of people. Therefore, boot camp and ice-breaking sessions have been held to increase the interaction between junior and senior engineers to increase the sense of belonging and eliminate the gap between them to create a vibrant team spirit.

Skills Gained

As it is the first year to implement some electronic devices as manipulators outside the ROV, our engineer has encountered some new waterproof techniques associated with using the housing. For example, we need to apply epoxy to the servo motors as a double safety and make a small waterproof housing for the peristaltic pump.

Future Development

Design

An in-house developing component is certainly one of our goals for future projects, for example, Field Oriented Control (FOC) ESC, as FOC can provide a higher accuracy and efficiency control on thrusters, especially under low RPM, achieving micro-manoeuvre for better precision. Moreover, in-house development is on auto-pilot. In the current commercial product that we adopted, its functionality might not be suitable for future development. Therefore, there is a need to design a comprehensive design that is most suitable for our development. Finally, in-house development of optical fibre transceivers based on FPGA is also one of our considerations. The product available in the current market is large and contains many unnecessary parts. There is a need to tailor-made for function and size reduction.

Design Process

Since this is the first year using multiple simulators, there is room for improvement. Through exploring the functions and usage of the simulator, we wish to master it before the next project. As a simulator provides reliable simulations which resemble the actual environment, it can greatly facilitate design and development progress, especially for prototyping and testing. Even so, the experience of using the simulator for Fronteer is very valuable and provided a good reference for future projects.

Project Management

To achieve better project management, get knowing each member's strengths and weaknesses- es will certainly improve the performance and productivity of the team in coming projects. From observation, there is an imbalance of workload between members. It is essential to pay more effort into familiarizing the team's pace. This can achieve better management in terms of task distribution and manpower mobilization, thus fostering effective collaboration.

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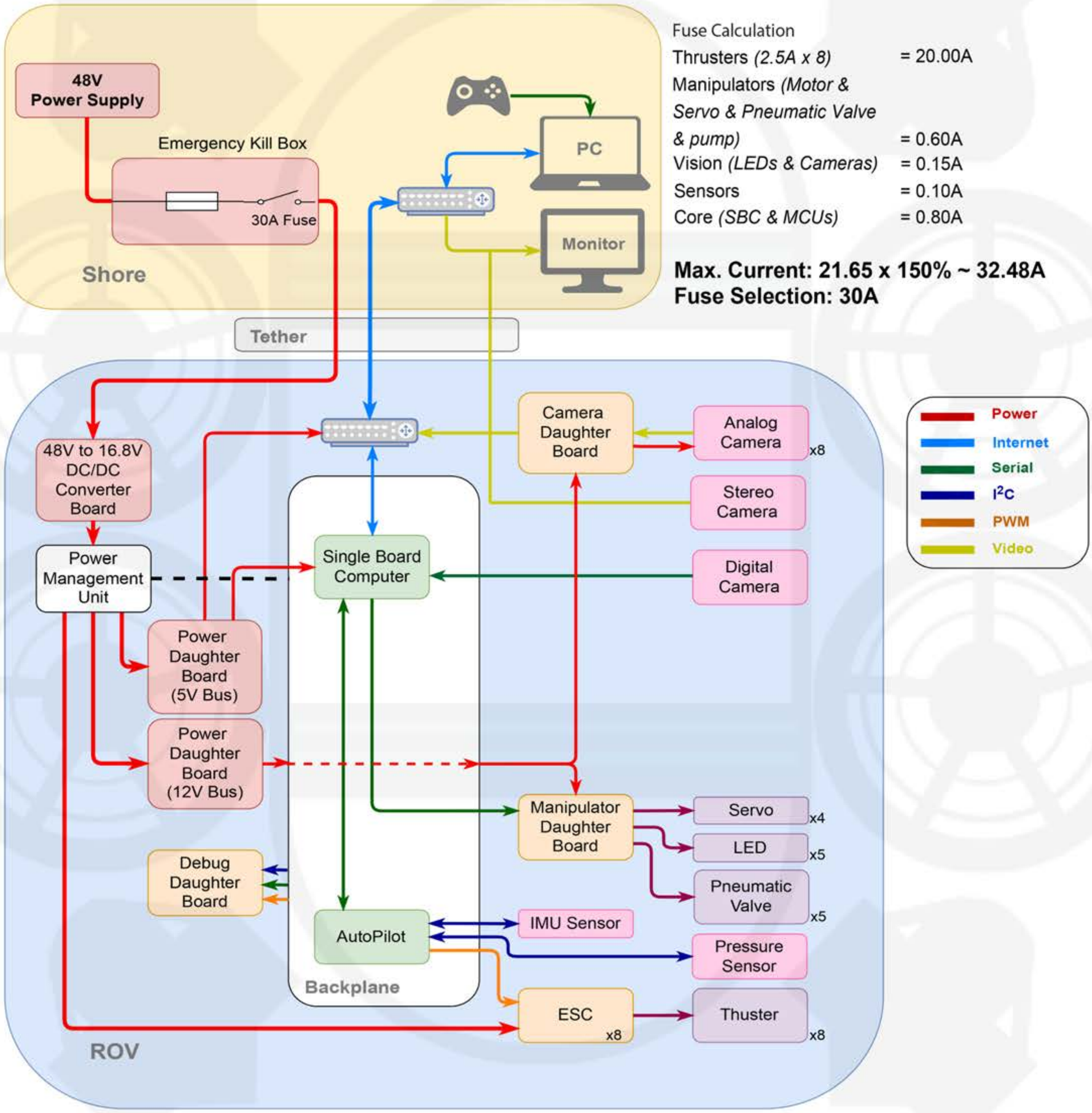
REFERENCE

MATE. MATE ROV Competition Manual Explorer. 2023.
https://20693798.fs1.hubspotusercontent-na1.net/hubfs/20693798/2023/2023_EXPLORER_Manual_FINAL_1_17_2023_withcover.pdf

Blue Robotics. T200 Thruster
https://www.bluerobotics.com/store/thrusters/t200-thruster/

Maxim Integrated. DS18B20
https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf

A. System Interconnection Diagram (SID) - Electrical

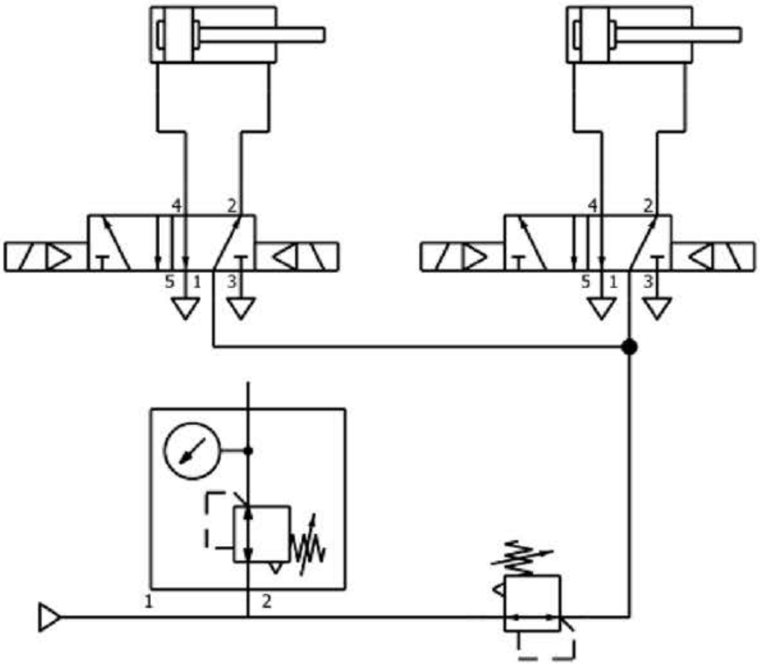


Fuse Calculation

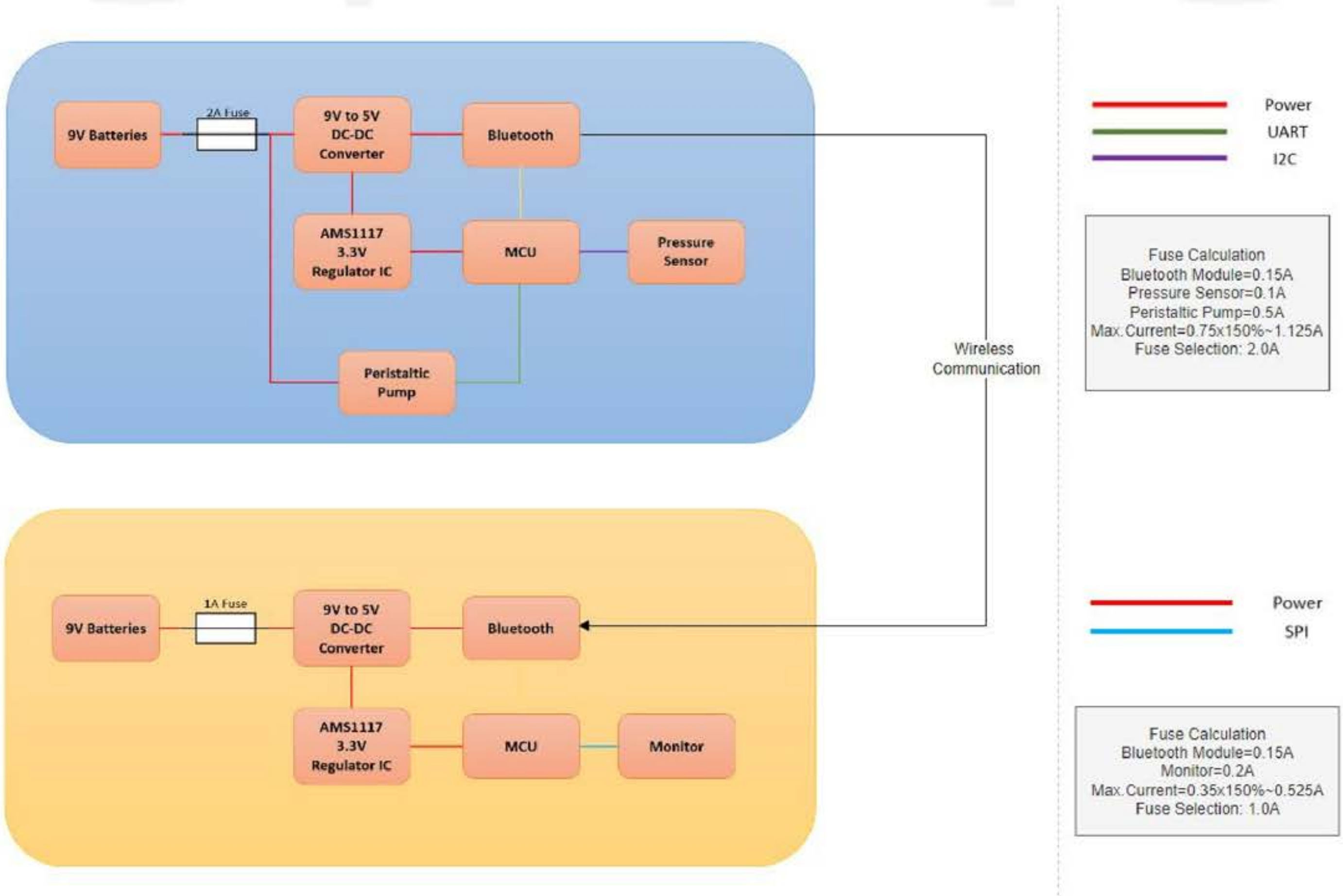
Thrusters *(2.5A x 8)*	= 20.00A
Manipulators *(Motor & Servo & Pneumatic Valve & pump)*	= 0.60A
Vision *(LEDs & Cameras)*	= 0.15A
Sensors	= 0.10A
Core *(SBC & MCUs)*	= 0.80A

Max. Current: 21.65 x 150% ~ 32.48A
Fuse Selection: 30A

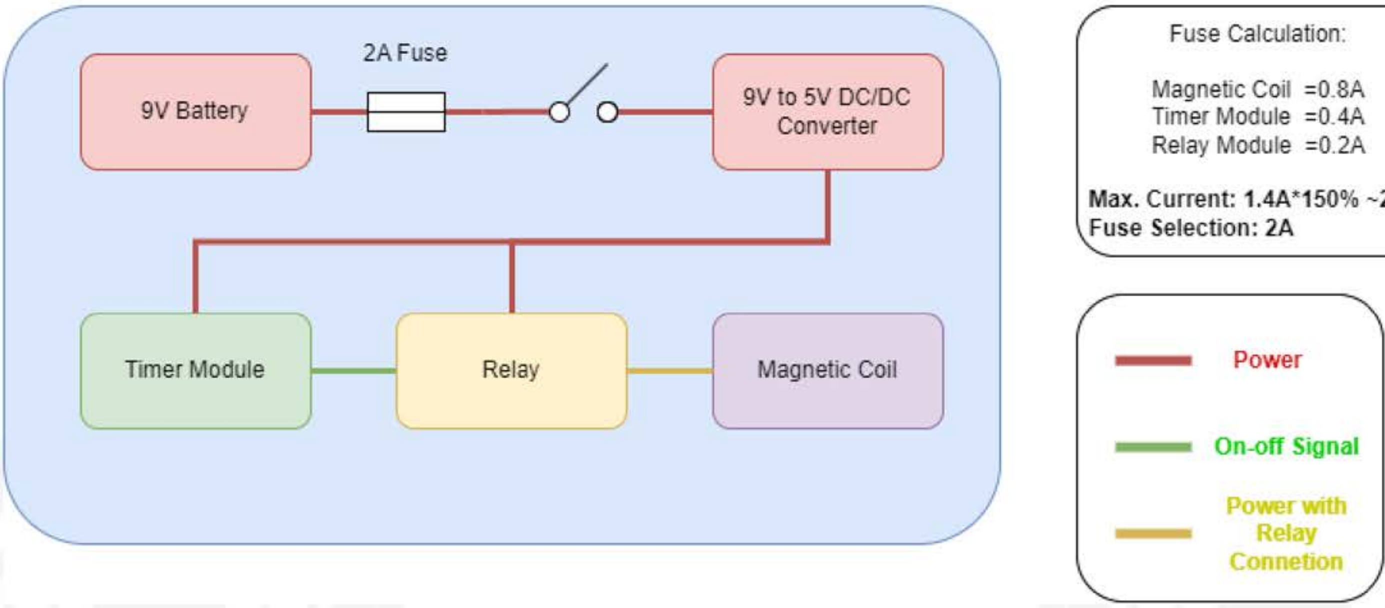
B. System Interconnection Diagram (SID) - Pneumatic



C.System Interconnection Diagram (SID) - Buoyancy Engine and Ground Receiver



D. System Interconnection Diagram (SID) - Fry Release Container



Fuse Calculation:

Magnetic Coil =0.8A
Timer Module =0.4A
Relay Module =0.2A

Max. Current: 1.4A*150% ~2.1A
Fuse Selection: 2A

E.Safety Operation Checklist

Operation Safety Checklist

Start-up Procedure		In Water	
Safety goggles are worn for every crew	☐	Tether man is attentively placing the ROV in water.	☐
All crew members are not dangerously near to the ROV	☐	Checked for bubbles that could mean any leakage.	☐
Ensured Main switches and circuit breaker on Surface Control Unit are off.	☐	Checked for all motors and servomotors functionality	☐
Checked that tether is connected to and from ROV is secure and non-damage	☐	If a burned out smell is detected, reel ROV back to surface as soon as possible	☐
Double checked that bolts are secure in position	☐	Everything is OK, begin mission	☐
Double checked that all jubilee clips are well tightened.	☐		
Double checked that all wires are properly connected, without any unwanted exposure	☐		
Double checked that all component's waterproofing status are nominal	☐		
Ensured that the thrusters are not obstructed by any sort of obstacles, such as wire	☐		

Upon Supplying Power to the ROV		ROV Retrieval	
Ensured that all member are away from the water	☐	Called "Prepare for surfacing"	☐
Informed everybody on deck before power is on.	☐	Ensured that crew members are ready for retrieval of ROV	☐
Ensured that all members are attentive and prepared	☐	Ensured the ROV is somewhere near to the crew	☐
Power source is switched on and connected to Surface Control Unit.	☐	Killed power after confirmation of retrieval	☐
Verified that the voltmeter reading is 48 volts on the LCD	☐	Ensured no power leak, called out "safe to remove ROV"	☐
Warned everybody on deck for thruster test	☐	"ROV secured on deck" is called out after ROV is secured	☐
Ensured that the GUI is started and codes are ready to run.	☐		
Ensured that the thruster test is properly performed without abnormalities	☐		
Ensured that no abnormalities (shoddy feed etc) are found on the display	☐		
Tested accessories	☐		

Launch		Loss of Communication / Unresponsive	
Hands are removed from the ROV control panel	☐	Checked if all connections are secure	☐
Called "Prepare to launch"	☐	Rebooted the communication system	☐
Ensured all deck members are ready	☐	If failed: pull out and plug all wires again	☐
Called "Launch"	☐	Troubleshoot succeed: mission continues as usual	☐
Ensured ROV is completely submerged to water	☐	Troubleshoot failed: Kill power	☐
Wait for release	☐	Retrieved ROV via tether	☐