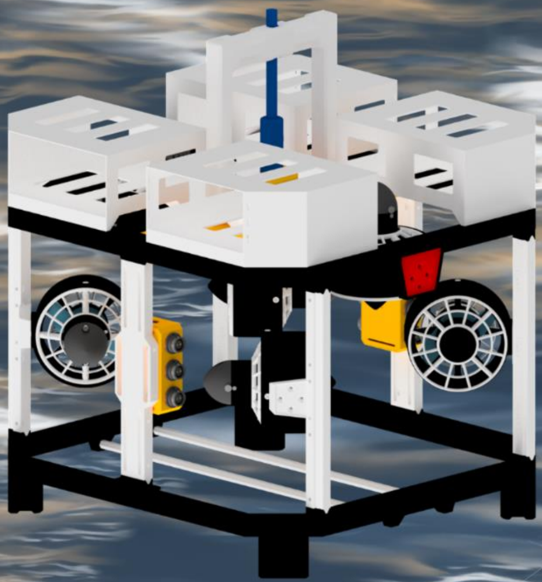
DELTA

TECHNICAL DOCUMENTATION 2021



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ABSTRACT

Sashimi is the first underwater Remotely Operated Vehicle (ROV) designed by Delta, created on the request for proposals by MATE ROV Competition and the demands of the global community, for an ROV for removing plastic pollution, lessening effects of climate change on coral reefs and maintaining healthy waterways. To meet these requirements, Delta developed a ROV, Sashimi, which features a flexible configuration, allowing it to adapt to a wide range of tasks. Sashimi is able to be used for cleaning the ocean by removing plastic debris from different levels of depth, perform maintenance on sea bins, move coral fragments to nurseries, cull Crown of Thorn sea stars and collect sediment samples in hard-to-reach areas.

Sashimi is the culmination of months of planning, developing, and manufacturing by Delta's 10 dedicated members. The ROV's pilot oriented design makes it easier to use and improves its functionality. Sashimi's structure is mainly 3D printed and reinforced with aluminum hex rods, allowing it to support standardized connections and have a modular layout. Size and weight regulations were also kept in mind when designing the Sashimi, allowing it to complete all tasks while maintaining a small profile. Maneuverability and ROV stability is achieved through the use of 6 T100 thrusters and placements of tools could easily be "hot swapped" between the two sides of operation due to the Sashimi's flexibility and standardized connections.

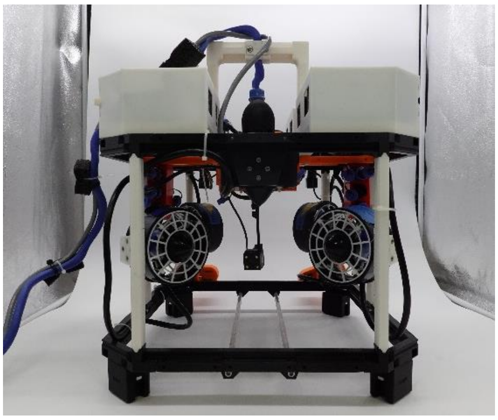

Figure 1 Front view of Sashimi

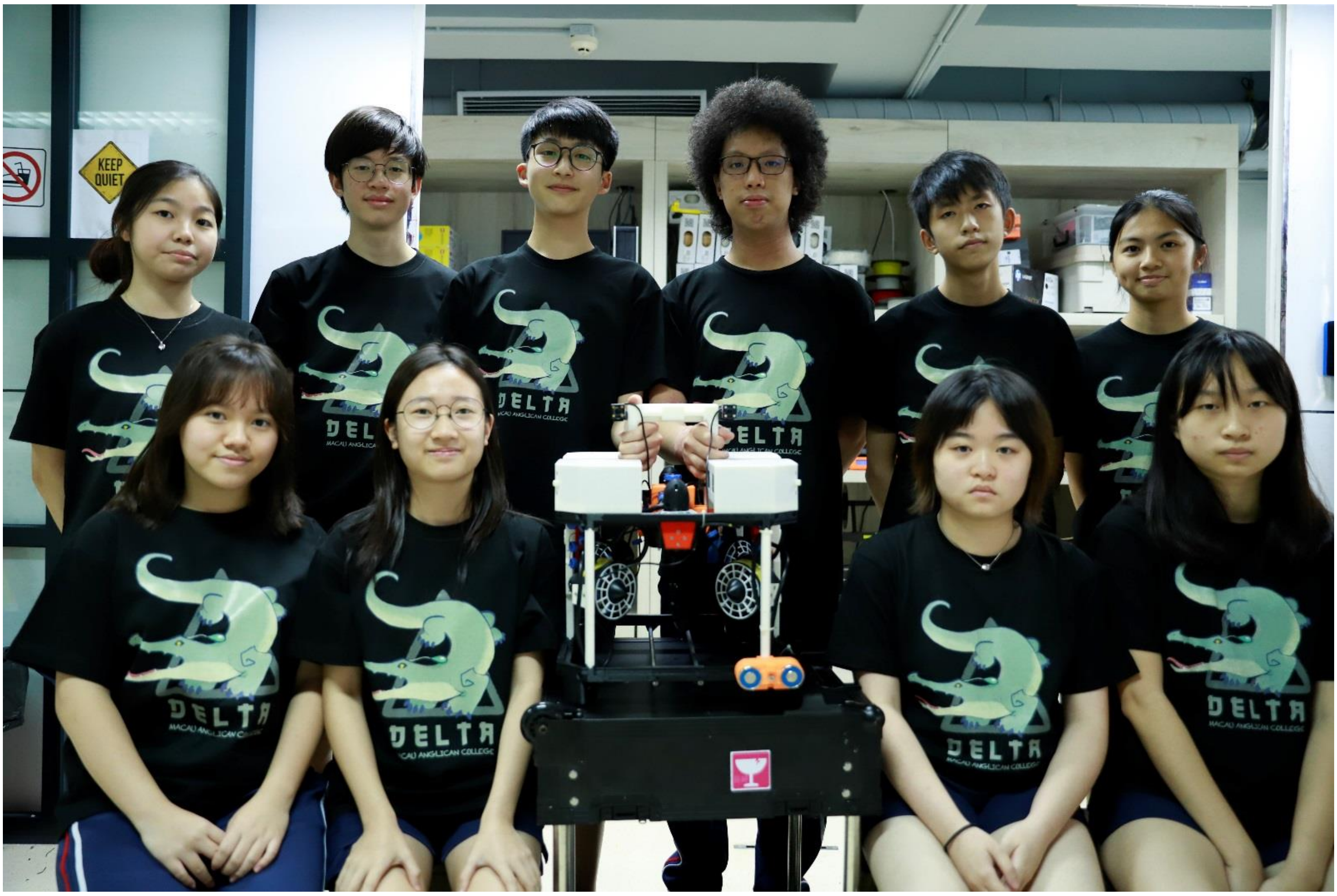

Figure 2 Members of Delta

The development period of Sashimi spans over an entire year with over four thousand hours of work dedicated to it. The market value of materials used on Sashimi is 10,170HKD.

PROJECT MANAGEMENT

Delta chose to learn and adopt Agile management to manage the progress of the ROV, specifically the Scrum method. Agile management is chosen as it focuses on continuous incremental iterations throughout the development of the ROV. This pushes the team to create a working product as soon as possible, allowing the team to use it as a platform for testing other tools and improving the control system. Agile management uses a broad vision set at the start of the project instead of a strict target, allowing for flexibility in execution and improvements to be added in the design process. If any issues are to arise during the design process, the process allows members to adapt and adjust to the conditions. Furthermore, Agile management minimizes the cost and time used on the ROV as members can provide ideas or solutions to complete or improve the task during its development period, instead of changing it after the task has been completed, making it suitable for smaller teams.

Scrum is one of the Agile project management methodologies. The organization method is made up of 2-4 week Sprint cycles to complete a deliverable goal at the end of each period. These Sprints add up to form the overall long-term plan by dividing the year into multiple manageable Sprints. The long-term plan is a timeline highlighting key milestones for releasing improvements throughout the year. It shows an overall vision of what tasks or goals should be finished in each sprint and the overall project. The short-term plans are targets created at the beginning of each sprint to inform team members what to focus on in the Sprint cycle and what tasks are needed to be completed in the month, contributing to the overall long-term plan. Both the long term plans and the short term plans are backlogs based on priority to ensure that urgent tasks are completed first.

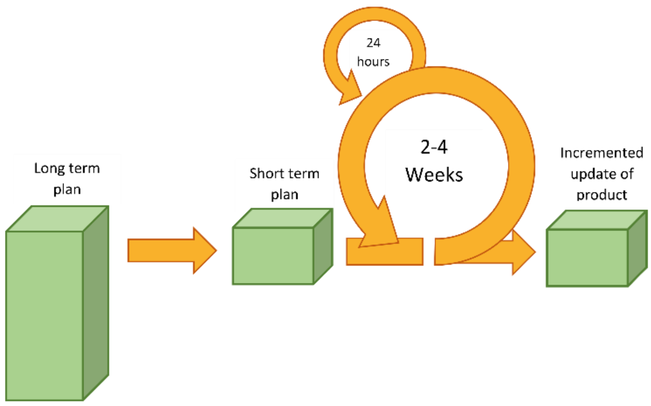

Figure 3 Scrum Diagram

Delta uses this specific method as it divides the year into multiple one-month Sprint cycles, allowing for rapid development and testing.

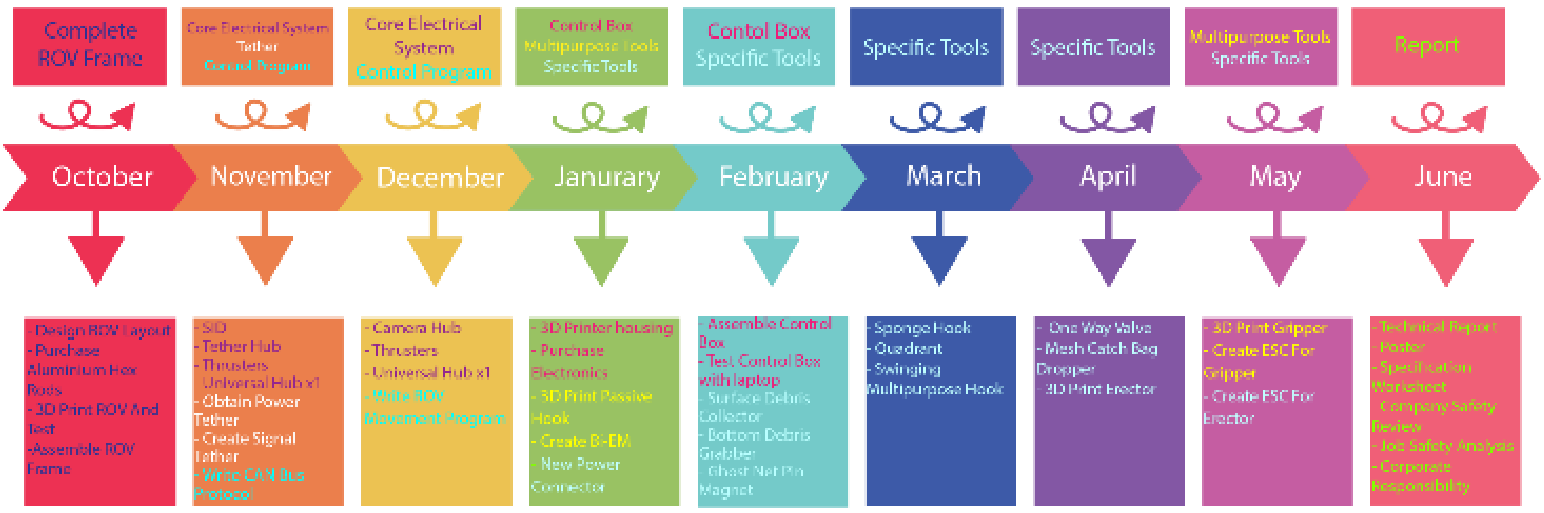

Figure 4 Release Planning

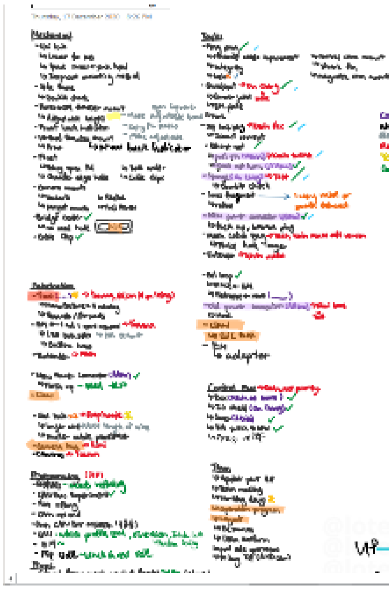

Figure 5 OneNote screenshot

Every day, the project manager goes through the short-term priority list to create a daily backlog of tasks to complete by planning, implementing, and reviewing their projects. The team then meets to discuss issues members are facing when working on their tasks, potential improvements to current designs, or items needed to be purchased for research and development. Scrum also allows a flexible work schedule as the year is split into multiple sectors. This means that the starts and ends of sprint cycles could be adjusted to accommodate unforeseen water trials, Covid-19 restrictions, scheduling issues, and examinations of team members.

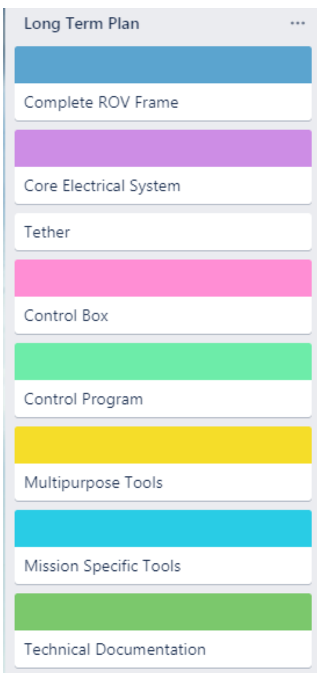

Figure 6 Long term plan

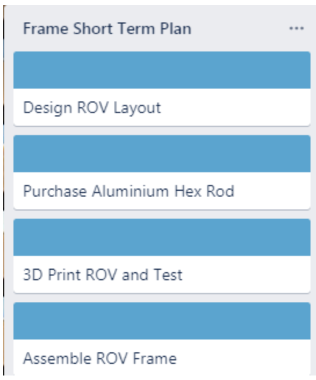

Figure 7 Short term plan

Delta implements Scrum by creating a long-term plan and multiple short-term plans to outline the tasks and goals of the project. At the start of the year, a backlog of tasks are listed out to be distributed and completed throughout the project. The tasks required are then noted onto a shared Microsoft OneNote document. The team prioritizes the tasks depending on their importance and urgency. For example, issues with the ROV control system will be prioritized over changing the details of a simple passive tool.

The team organizes its members into multiple departments. This includes mechanical design, electrical engineering, software writing, and manufacturing. Team members join these departments depending on their preferences and the team's needs, and members may join multiple departments depending on their interests and skills.

A team meeting is held at the beginning of each Sprint to review the progress from the previous month and distribute new tasks to members. This cycle repeats throughout the project to ensure that each Sprint backlog contains the tasks necessary to fulfill the long-term plan and project deadlines. In regards to resources, the meeting also includes the discussion about the purchasing of resources. For development of new components, requests are made by team members, with the costs needed added to the company finances. When requesting resources, team members first state their task in the Sprint cycle and what resources they need for it. The items are then purchased on the internet or at local stores by the CFO or by members under the surveillance of mentors. If there are issues with the product, new resources are bought to better suit the needs of the sprint. However, a cut-off day is set during the sprint meeting as items may not arrive in time to meet the deadlines.

DESIGN RATIONALE

ENGINEERING DESIGN RATIONALE

Delta's engineering design rationale focuses on the safety and functionality of the ROV. Aside from these principles, Delta also prioritizes pilot-oriented design, ease of use, ease of maintenance, and ease of manufacturing in their respective order. The goals of the design rationales combine to reduce risks such as technical debt and failures in the final product.

To ensure the safety of personnel, wildlife, and the environment, Delta has various protocols that members are required to follow. Additionally, safety features are implemented on the ROV which includes components such as thruster shrouds and fully sealed electronics.

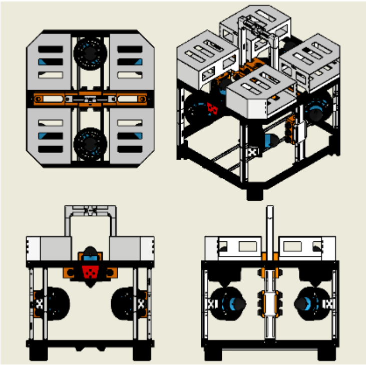

Figure 7 Blueprint of Sashimi

Regarding functionality, the ability to complete all competition tasks in the allotted time is evaluated extensively. A systems approach is used to ensure a successful approach to each task while other tools are not affected.

Orienting the ROV's design around the pilot is important as it increases the efficiency and performance of Sashimi when completing tasks. Delta achieves this by coordinating the placement of cameras and tools along with the operation program and the design of tools depending on the pilot's feedback after water trials. Controls of the ROV are also customized to complement the pilot's desire.

Ease of use is promoted by Delta through maximizing the visibility of tools and increasing the stability of Sashimi through the use of precise camera placements and neutral buoyancy. All of these features allow the pilot to have better control over the ROV during competition runs, thus increasing the efficiency of Sashimi in water.

Ease of maintenance is enabled through the use of modular parts, standardized systems, and simple designs. The standardized systems such as the Standard Mounting System for mechanical parts, CAN bus for electrical systems and Universal Connectors for electrical connections allow for quick and simple maintenance. Parts on the ROV could be easily removed and replaced when broken as the parts are made modular. Passive and simple tools are often chosen over active ones as they are more reliable and lower the chance of failure. Epoxy cast electronics are also used to prevent malfunctions in the system due to water damage.

Ease of manufacturing is achieved through the use of 3D printing. The additive manufacturing technique allows for quick prototyping, consistent quality and little geometric constraints while being simple to use. 3D printing also enables the team to work on other tasks while parts are being created, as the process is automatic and hands free.

BUOYANCY AND BALLAST

Neutral buoyancy is essential in making the ROV easy to use and stable when performing tasks. To offset the negative buoyancy of the ROV, foam is added into 4 float chambers at the top of it.

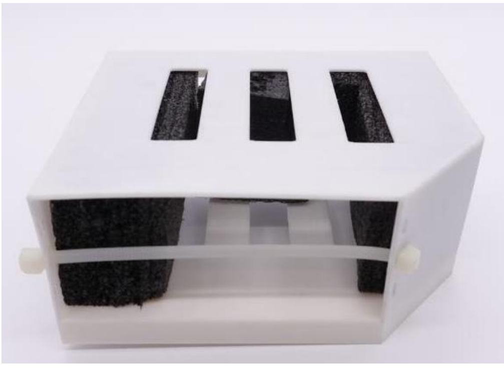

Figure 8 One foam chamber

Foam is added at the top instead of the bottom to prevent tipping or flipping of the ROV and to increase stability when moving. Different amounts of foam are needed in each chamber due to the uneven placement of tools and their individual weights, thus buoyancy is tested before each water trial to fine tune and adjust the amount of foam needed to achieve neutral buoyancy.

To increase the stability of the ROV, stainless steel ballasts are placed at the bottom corners. This is because the increased weight lowers the center of gravity, thus increasing the overall stability of the ROV when moving.

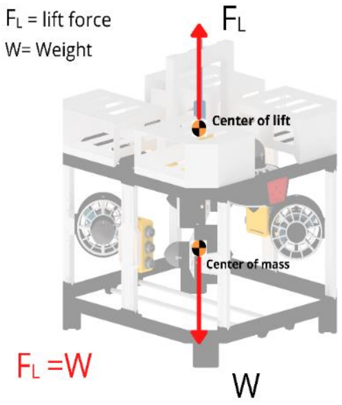

Figure 9 Centre of weight and buoyancy

PROPULSION

6 Blue Robotics T100 thrusters are used to propel Sashimi underwater, with 4 placed horizontally and 2 vertically. The 4 horizontal thrusters are located on each corner of the ROV at 45 degrees relative to the front and sides, allowing for both longitudinal and lateral motion while the 2 vertical thrusters are mounted at the top of the ROV for vertical and pitching motion. The 6 thruster configuration was chosen as it gives 5 degrees of freedom while being very stable, allowing the pilot to easily execute tasks underwater with ease.

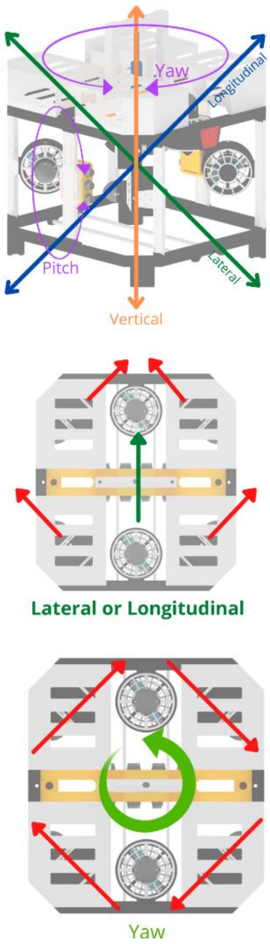

Figure 10 5-DOF by six thruster configuration

Blue Robotics thrusters are chosen specifically as according to our testing, the T100 thrusters produce a large force while being compact and power efficient, making it a good choice for our power budget. Delta learnt from Fish Logic to integrate the ESC and CAN bus electronics into a streamlined SLA housing.

Figure 11 Thruster ESC casted in housing

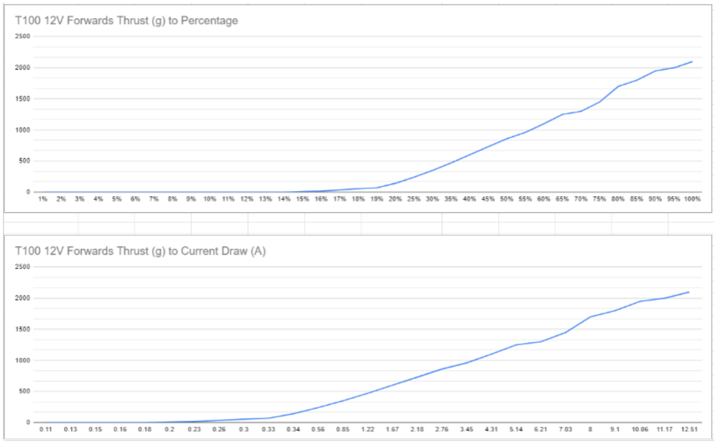

Figure 12 Thrust test result

VEHICLE STRUCTURE

MATERIAL CHOICE

Delta chose 3D printing as its main method of manufacturing over subtractive manufacturing methods such as CNC (Computer Numerical Control) due to its increased flexibility, allowing for more geometrically challenging designs to be produced, maximizing the functionality of the ROV. 3D printed parts are also consistent in quality and the printers are easy to operate, allowing for rapid prototyping and boosted workflow. This is further aided by the hands-free characteristic of 3D printing, allowing members to design or improve tools when the parts are being printed. Furthermore, 3D printing reduces waste created, lowering the overall cost of the project.

PLA+ was the chosen material for every printed part in the ROV. This material is usually a blend of PLA (Polylactic Acid) and other plastics or pigments to help improve the weakness of standard PLA. Filaments such as ABS and PETG were not selected despite being commonly used due to their frequent warping issues, and the 60% increased cost of the material. PLA+ is also biodegradable as it could be broken down by bacteria, lowering the environmental impact of the ROV.

Aluminum hex rods are also used inside the 3D printed structural parts of the ROV frame to increase the strength and rigidity of the ROV. Hex rods allow for screws to connect pieces together as their ends are threaded, making for a compact yet durable joining method profile.

SMS

Delta uses a mounting system developed by Fish Logic called SMS4 (Standard Mounting System 4) as it suits the design rationale used and has proven to be strong as well as reliable. The system consists of 2 components, the rail and the bracket. The SMS is a standardized, easy-to-operate mounting system that provides both quick release and quick mounting, which is especially important when swapping tools.

The rail acts as both a mounting system and a structural piece as most, if not all, of the ROV's structure is based on the SMS. The rail has an indent for the bracket to attach to, and is supported by hex rods. The rails provide a lot of mounting space that allows any tool or camera to be mounted onto any of the rails.

The SMS bracket consists of three pieces along with a single M5 internal hex screw and nut. Using the indent on the rails, the tool can be mounted without fully securing it into place, which makes adjustment extremely easy.

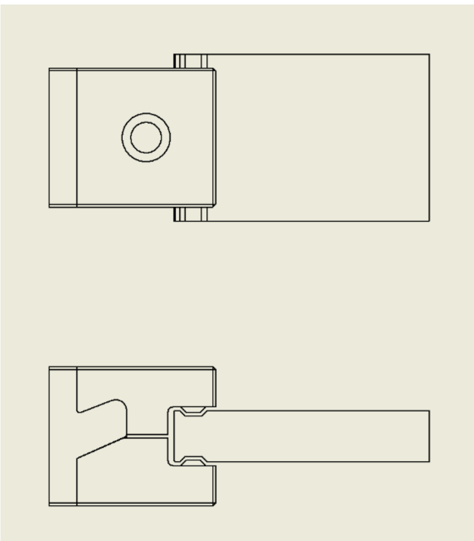

Figure 33 SMS Top and Side view

A micro SMS developed by Fish Logic is also present on the ROV. The design has a smaller profile as it is mainly for smaller lightweight tools such as cameras since they do not require as strong of a mounting system compared to other tools.

MAGNETIC CAMERA MOUNT

The magnetic camera mount is developed by the Fish Logic team and is adopted by Delta as it is compatible with our needs of helping improve our ease of maintenance.

It is designed specifically for cameras to be quickly swapped to different setups or to be removed quickly. This is very important, as it reduces the amount of time the ROV needs to be on the poolside before it can be deployed again. There is a magnetic stud located on the mount itself which makes changing camera positions extremely easy since it is just pulling the camera out and snapping it back in. Cameras can also be rotated 90 degrees when mounted.

The magnetic camera mount is mounted onto a Micro SMS, which is a more compact version of SMS4. When mounted on the Micro SMS, the camera's field of vision can be easily changed according to the pilot's preferences.

Figure 14 Magnetic Camera Mount mounted onto Micro SMS

ELECTRICAL SYSTEM

SID

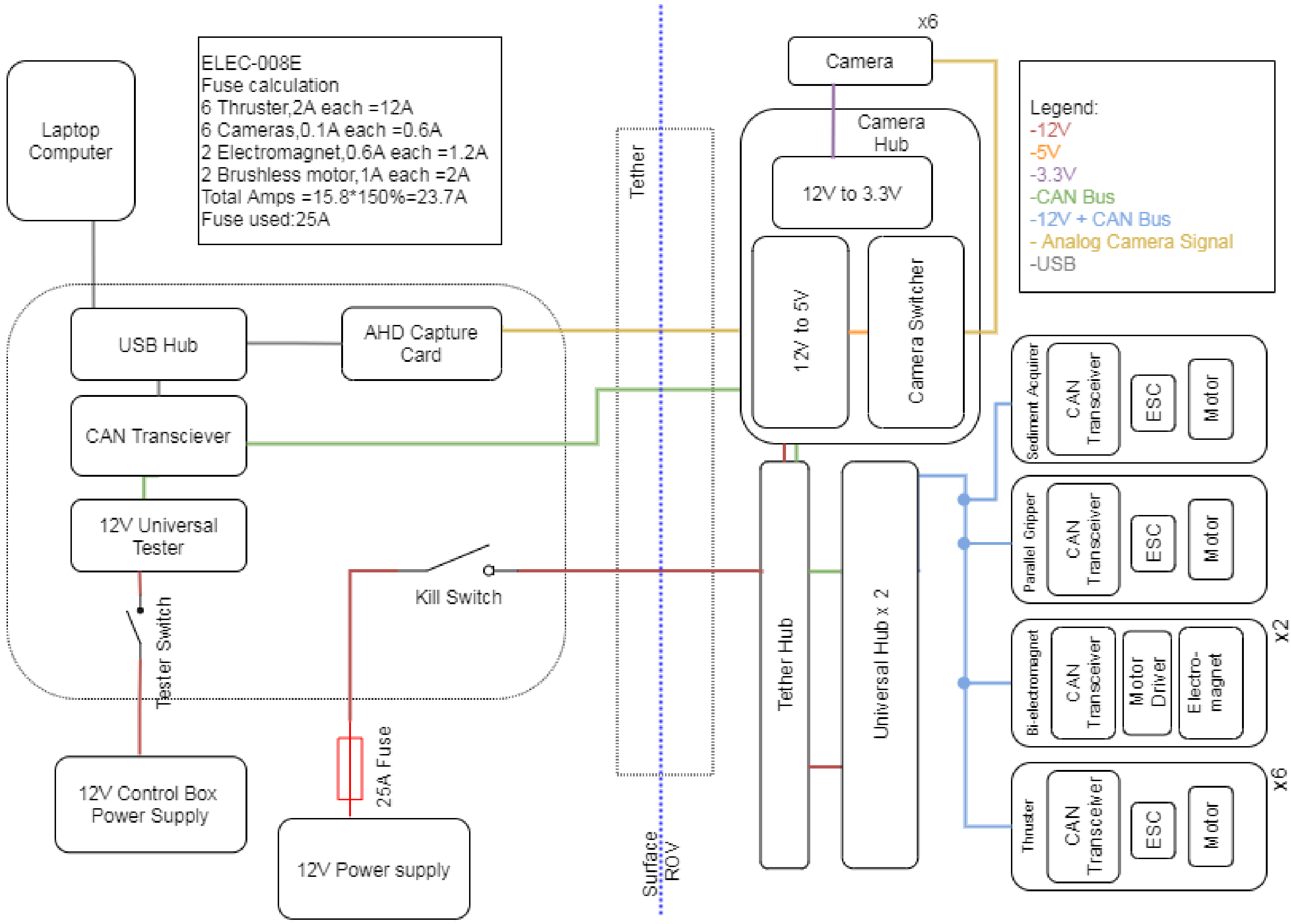

Figure 15 System Integrated Diagram

UNIVERSAL HUBS

The Universal hub is for distributing power and routing CAN bus to the control hub and throughout the ROV system. It allows 2 EMs, 6 thrusters, and ESC of the claw to be plugged into any of its sockets. It is connected to the tether hub. There are 2 universal hubs in total and one on each side of the ROV. It is 3D printed which consists of 6 sockets on each hub and an LED power indicator.

Figure 16 Universal Hub

UNIVERSAL CONNECTORS

Delta uses universal connectors for tools and thrusters. For this, connectors from the Weipu SP13 series are used, which are small plastic shelled IP68 waterproof connectors. Pins 1 and 2 are used for power, 3 and 4 for grounding, 5 for CAN-H (Controller Area Network - High) and pin 6 for CAN-L (Controller Area Network - Low).

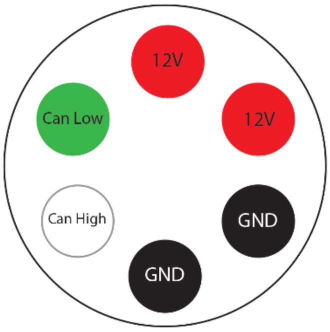

Figure 47 Universal Connector

Each connector delivers both power and signal, which significantly speeds up the process. Epoxy is injected inside the cable connector for waterproofing, and silicone grease is distributed evenly on the mouth of the cable connector.

TETHER

The ROV tether is a used part from the Blazin' Hydra ROV from Fish Logic. The power cable is used because it meets the ROV's power requirement of 25A. The signal tether is a Cat5e cable which consists of 4 twisted pair cables. Since CAN bus only requires one twisted pair, the other three twisted pairs are used for the 3 camera channels.

Figure 18 Rolled Up Tether

CAMERA SYSTEM

The camera system consists of a capture card located within the control box which acts as an ADC that converts analog data from the 6 Analog High Definition (AHD) cameras into digital data that our laptop can process and display on the monitor, allowing the pilot to navigate in the water and estimations to be calculated.

This camera system consists of a camera hub onboard the ROV which allows different views to be toggled.

CAMERAS

The ROV is equipped with 6 cameras, 2 being primary cameras providing a front view for both driving directions and 4 being secondary cameras mounted onto any SMS rail to provide extra viewing angles for tools that require precise maneuvers to complete tasks as quickly as possible.

Wide-angled analog 720p cameras are used instead of digital cameras because they are lightweight, waterproofed by the manufacturer and they offer lower latency compared to digital cameras.

Figure 19 Camera

CONTROL BOX

The ROV control system consists of a laptop and a 3D printed control box connected using USB-C. The laptop is used to run the command program as well as displaying the GUI and display camera feeds. This is chosen over using single-board computers such as the Raspberry Pi because the hardware on the laptop is faster and it also has a large 1080p monitor and keyboard integrated making the system easily transportable. The 3D printed control box consists of an AHD capture card to input all 3 channels of camera feed and a CAN to USB to receive and transmit ROV commands and a USB hub to connect all electronic parts to one USB-C cable leading to the laptop.

A kill switch is installed to quickly switch off the ROV in emergency cases. A 6 pin socket for universal connectors is also featured on the control box to easily test electrical parts without setting up the ROV. No AC power is used in the control box.

Figure 20 Inside of Control Box

CONTROL SYSTEMS

CAN BUS

CAN bus, or Controller Area Network, is a message-based protocol that enables all individual systems, devices, and controllers within a network to communicate with each other, without the need of a host computer. CAN bus works by utilizing separate wires known as CAN high and CAN low, which carry different voltages when in use, specifically when data bits are being sent CAN high reaches the voltage of 3.75 whilst CAN low is at a voltage of 1.25V. This voltage differential is what allows for communication between the CAN bus devices.

Delta has chosen to use the CAN bus system due to the various technological improvements over prior technologies for communication. The CAN bus System has built-in-error detection, which prevents errors from affecting the rest of the system. Built-in-error detection ensures the system stays efficient and does not suffer from avoidable stutters or crashes.

The CAN bus system is reliable as it is designed for robust performance under harsh environments and is less susceptible to noise and magnetic interference, which may be present due to the functionality of certain tools. This reduces the possibilities of control and communication failures between the on-the-shore team and the ROV.

Overall, the CAN bus technology has been proven to be more efficient and quicker at data transfers whilst being more reliable in a wide range of scenarios.

Figure 21 CAN Beetle module

In conclusion, Delta chose CAN bus as its communication method as while RS-485 has high bitrates and long distances, it is not designed for bus systems and requires software to handle the addresses of each module, making it very resource consuming. I2C was also not used as it is incompatible with our length requirements, and

	CAN bus	I2C	RS-485
Maximum bitrate (At the length of tether)	1 Mbit/s	N/A	2 Mbit/s
Maximum Distance	1000m at 10 kbits/s	10m at 10.24 kbits/s	1200m at 100kbits/s
Error Detection	Uses error counters	Unavailable	Uses parity bit
Master Slave	Multiple masters	Single master	Single master
Addressing system	Message ID hardware built-in	Hardware built-in address	No hardware address and relies on software protocol
Support	Needs separate transceiver and controller for Arduino	Available on many hardware including Arduino	Needs separate transceiver and controller for Arduino

even when I2C extenders can be used as done by Fish Logic previously, the signal is unreliable and has a lower bitrate. Therefore, CAN bus was chosen as it has a high bitrate while meeting the length requirements of the tether. It also has built-in message IDs in each module, allowing broadcast messages and connecting of external devices to monitor or diagnose the network.

VEHICLE CONTROL PROGRAM

The Entirety of the Control Program is written in python, which allows for easy on-the-fly editing of code if necessary through a python IDE (Pycharm) by those located on the shore side. Despite the utilization of Python, a high level language, the difference in optimization and performance is unnoticeable and is a good compromise in order to decrease time in development.

Pygame, an Open Source Python Library, has a feature set that is capable of handling both the digital input and graphical output of the Control Program, which limits the number of libraries needed along with decreasing the clutter and inefficiency of the program. Another benefit of using pygame, an open-source module as our foundation, means that the library has been tested by countless programmers, which assures a certain level of stability.

By Setting Python and Pygame Library as the primary foundation for our control program, Delta gains numerous advantages. Our Program has support for numerous types of control devices, such as Xbox Controllers and Playstation Controllers along with compatibility with multiple Operating Systems. Due to this high level of compatibility on both the software and hardware front, Delta can run the control program on almost all devices that support Python, CAN bus and input from controller devices. This, in turn, has enabled us to directly run our control program off the in-house developed control box along with a standard laptop.

A majority of the controller is mapped to be directionally and functionally identical to those of First-Person-Shooters in order for the ROV control scheme to be more intuitive and standardized. The standardization would make the learning curve for the ROV's operation less steep, as muscle memory developed playing video games can be directly transferred to the remote piloting of the ROV. Some aspects of the controller layout are designed to optimize the performance of pilots during mission-runs. The orientation of piloting the ROV can be switched if necessary, with the front and rear of the ROV being swapped in order to accommodate a variety of maneuvers during Mission-Runs.

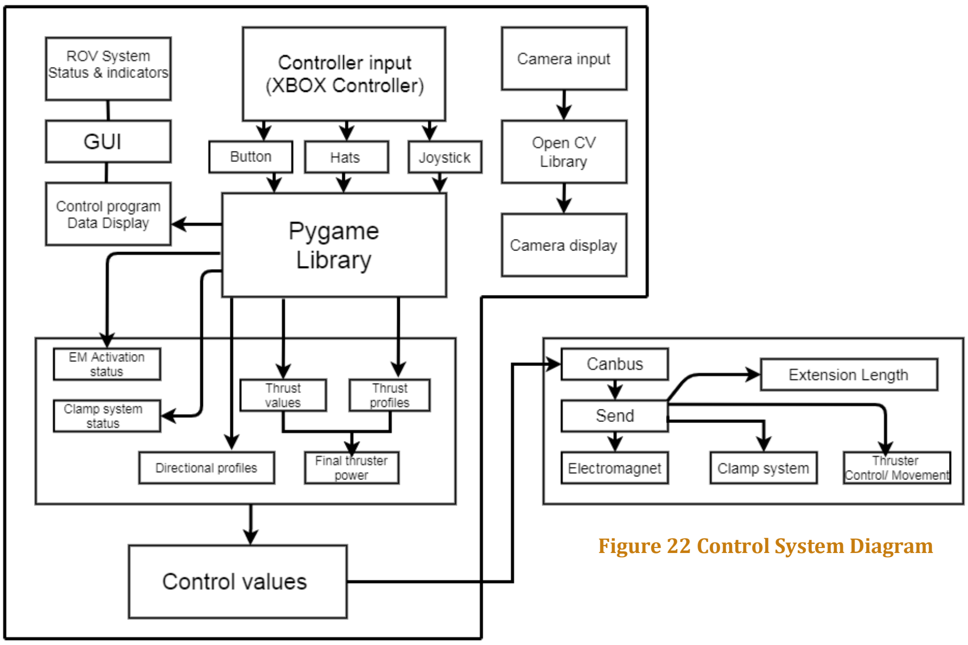

Figure 22 Control System Diagram

The Pygame Library is capable of reading the exact values of both joysticks of the controllers. All of the joystick values are then take into account in order to calculate the values that directly corresponds to each thruster's output orientation and power, which means the output power of specific thrusters could be modified if needed along with allowing for the inversion of the thrusters if the hardware is orientated incorrectly without having to physically alter the position of the thrusters. In addition to the aforementioned, profiles have also been integrated into the system which allows for the maximum power of thrusters to be capped on the fly, which range from a “Fine” to a “Coarse” adjustment.

The mapping of the controller was done in order to help to maximize its versatility, through the use of toggles when possible and removing any redundant button placements. This allows for future implementations of active tools that require direct pilot-control. The mapping and the control for each tool used was written separately, and tested before implementing it into the rest of the control Program.

The OpenCV Library is used in order to display the visuals of the 6 separate cameras, with the help of the library’s built in Video Capture functionality. We chose to use the OpenCV library on python as opposed to other methods of viewing the camera input, as it provides higher stability than the 3rd party software that we have previously tested. Utilizing OpenCV also makes it easier to integrate into the rest of the Control Program, which would reduce time needed on preparation. The Control Program allows for the pilot to switch between two sets of 3 cameras when needed with a toggle located on the control.

The OpenCV Library includes built-in functionalities that allows for resizing and recontextualizing for more specific purposes in the future, which allows us to directly build new features onto our pre-existing foundation; for example object detection and other forms of image detection, whilst limiting any potential new headroom requirements from being introduced.

In summary, Delta’s Control Program has been programmed for maximum efficiency and intuitiveness, by using two Open Source frameworks, Pygame and OpenCV as our foundation.

GUI

Delta has opted for a simplified GUI without any unnecessary design elements that would clutter its User Interface. Due to the Pygame Library’s inclusion of native support for basic 2D Shapes, indicators can be easily fashioned for the Pilot and commander to analyze data during the mission runs. Native support helps to cut down on time needed to be spent by the programmer on an accessible and usable version of the GUI, as well as the range of indicators and statuses to ensure the pilot and the commander are kept well-informed of the ROV’s condition.

Pygame allows the on-screen elements to be refreshed at 60 FPS due to the minimalism of the interface, creating a responsive GUI, and mitigating any mistakes from the pilot’s end that may occur.

However, due to the limitations of pygame, we are unable to implement alphanumerical labels to indicate the purpose and display the direct values for each indicator, but the non-reliance on text labels is actually an advantage. A multi-colored and rudimentary design for the Graphics User Interface provided drastically better visual clarity of the system. This arrangement allows for quicker response times from the Pilot and the Command, as it is faster than reading labels, providing a less cumbersome experience. This improves efficiency in decision-making and prevents any stutters and confusion during the operation of the ROV.

The User Interface consists of colored bar graphs for the thruster output and indicators for crucial units of the ROV’s operation, such as the EM and

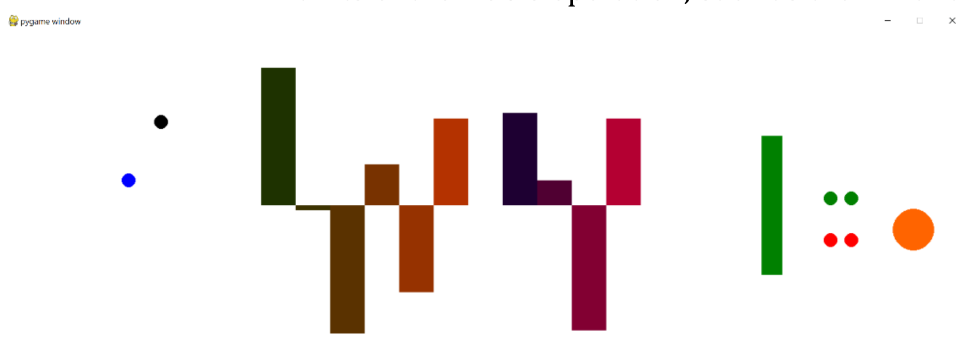

Figure 23 GUI

the status of the Clamp, meaning that troubleshooting can be easily done. Poolside members will not have to dig through layers of Input and Output Data to find the source of the issue, as all the crucial information data is visualized in a simplistic yet comprehensive manner.

Adjacent to the Pygame display interface that is used to display data for the controls, Delta has also implemented a camera system that is capable of displaying 3 cameras at the same time at a resolution of 1280 X 720. Delta has decided that this is the best compromise between the visibility of the display of the cameras and versatility. By limiting to 3 cameras at a time on the GUI, the usage of the resources of the laptop are also kept at a sensible level and prevents the system from becoming overwhelmed.

MISSION SPECIFIC

BI-ELECTROMAGNET AND ATTACHMENTS

The Bi-Electromagnet (Bi-EM) is a semi-active tool used to attempt 5 different tasks including coral injection, quadrat placement, replacement of the eel trap and mesh catch bag as well as installation of the new power connector. Bi-EMs are used instead of other active tools because they are more versatile in function and reliable due to less moving parts.

An adapter plate is located between the Bi-EM and SMS, allowing the tool to be turned and placed on both vertical and horizontal rails depending on the needs of the tasks. A 3D-printed U-bolt hook is added to the Bi-EM as an accessory which provides extra support and reduces risk of dropping the payload in case the electromagnets malfunction.

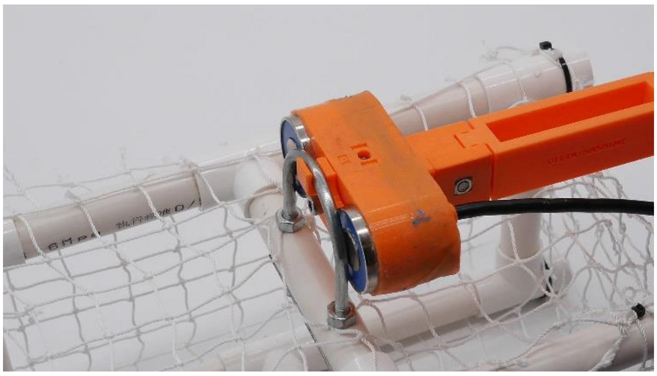

Figure 24 Bi-EM and U-bolt hook holding eel trap

BOTTOM DEBRIS GRABBER

The Bottom debris grabber (BDG) is a passive gripper used to collect debris at the bottom of the sea bed and is positioned on the bottom rail. A rubber band holds two claw parts closed and is forced open when a PVC pipe is pushed into it due to the slanted edges of the claw parts. These slanted edges also guide the PVC pipe into a circular chamber and the pipe is secured into place by the rubber bands mentioned earlier.

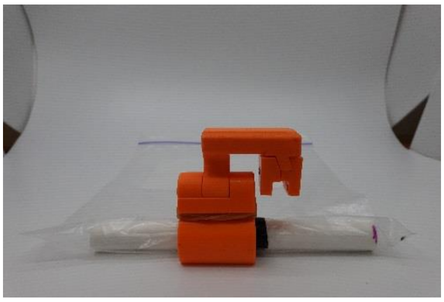

Figure 25 and Figure 26 Bottom Debris Grabber

NEW POWER CONNECTOR

The New Power Connector (NPC) provides power to the seabin. The transmitter side of the inductive coupling power connector is super-glued and epoxied in a cap-like structure on the bottom of the tool. A tall arch and washer above the cap allows it to be mounted onto the ROV by activating the electromagnet and deployed into the designated location by deactivating the tool. The arch allows alternative ways of mounting to the ROV such as a simple hook, in case that the Bi-Electromagnet does not function properly. The NPC's cable passes through a hole in the cap and arch to prevent tangling. The cap and the arch are 2 separate parts so that if an error occurs on

Figure 27 New power connector

the inductive coupling power connector, the whole tool does not have to be scrapped; only the arch or the cap. The arch is screwed onto the cap using M3 screws, allowing its overall structure to be simple and lightweight, ensuring the NPC will not fall off the electromagnet easily during mission runs.

QUADRANT

The quadrat is a tool that marks out an area on the mussel bed, allowing the amount of mussels to be estimated through a mathematical formula. It was made according to the requirements provided by the MATE ROV Regulations, with the inner dimensions of the quadrat being set to 50cm by 50cm. The quadrat was constructed from carbon fiber rods in order to ensure that it remained lightweight whilst still retaining high levels of durability and strength. Delta opted for carbon fiber rods with 4 flat sides, as it allows extra parts to be secured onto the quadrat without it being tilted to one side. The rods are joined together using 3D printed connectors and a set of M3 sink head screws, allowing them to be easily disassembled and reassembled at any time to save space during transport.


Figure 28 Quadrat

A quadrat Washer Mount system is utilized in order to attach the quadrat to the ROV. The quadrat Washer Mount connects the quadrat to the Bi-Electromagnet, which is mounted to one side of the ROV. This mounting system allows the quadrat to be easily deployed from and attached to the ROV by toggling the Bi-Electromagnet used.


Figure 29 Quadrat hook


Figure 30 Quadrat washer mounting system

An extra quadrat hook is mounted on the SMS Rail opposite to the Quadrat Washer Mount system to make sure that the quadrat itself won't shift or tilt towards one side and instead remain secured to the ROV. The hook is set at an angle which allows the quadrat to be held in place when the Bi-Electromagnet is activated and slip off when the tool is turned off, aiding the deployment of the quadrat.

SURFACE DEBRIS COLLECTOR

The Surface Debris Collector is a passive tool that allows the collection of floating debris in bodies of water. When the ROV drives above the debris, in this case ping pong balls, the ROV will descend, the ping pongs will enter the frame due to its positive buoyancy on water, and the frame will trap the debris, because the weight of the debris does not provide enough force for it to escape from the cage.

The width of the cage is the same width of the ROV to maximize the amount of space in which the debris can enter the cage. The opening of the cage consists of 2 nylon strings connected through each side of the frame, with the distance between them being smaller than the debris. This allows the debris to enter the frame as the strings stretch, while blocking the debris from escaping.

2 screw tensioners allow for the adjustment of the amount of tension for each nylon string. Tension of the Nylon strings could be varied for different types of surface debris. A carbon fiber rod is used to connect the cage to the ROV handle,


Figure 31 Surface Debris Collector

which prevents the PVC frame from getting in between the cage and the camera, obstructing the ROV's movement whilst strengthening the tool's frame. The cage is square-grilled to allow cameras to easily see through the tool and confirm if the task is completed properly. 2 top plates of the tool are slanted to prevent ping pongs from being stuck on top of the cage.

GHOST NET PIN MAGNET

The Ghost Net Pin Magnet (GNPM) is a powerful neodymium magnet used to retrieve the pin from the ghost net along with freeing the ghost net. The tool is positioned on the vertical corner SMS rails and the magnet is held using an SMS4 clamp held by a screw, allowing it to be loosened and face the direction of the ghost net pin. GNPM takes advantage of the ferrous properties of the pin, allowing the task to be performed efficiently and reliably. This task is completed by attracting the rounded edge of the pin to the magnet and pulling it out, allowing it to be secured tightly to the neodymium magnet and releasing the ghost net.

Figure 32 GNPM attracting pull pin

SPONGE HOOK

The Sponge Hook is a simple passive tool that collects sponge by hooking onto the string of the top coupling in the sponge sample retrieval task.

Figure 33 Sponge hook collecting sponge

Delta has chosen to use the string as the retrieval point instead of designing a tool to directly grip onto the coupling because directly contacting the coupling could lead to the below couplings from toppling. The string provides sufficient separation and distance from the other couplings, minimizing the risk of the structure toppling over. The curved shape of the Sponge Hook along with its long length and width ensures that the sponge would not slip off midway during the retrieval of the sponge.

ONE WAY VALVE

The One way valve is a Y-shaped tool with a 22m wide slot and a magnet bar that allows the retrieval of the Old Power Connector (OPC). When the tool contacts the OPC, the magnet bar will fold itself into the tool, allowing the entrance of the OPC. After the OPC enters the valve, the magnet bar will return to its original position as the poles of the magnets repel, preventing the connector from exiting the tool.

The one way valve is mounted on the vertical or horizontal rail of the ROV with SMS depending on the operation necessities. The valve consists of a pair of repelling 10x5 mm bar magnets which are attached on the valve itself and the magnet bar, along with a pair of slopes on each side of the valve to prevent the rotation and dropping of the OPC. Also, the valve is designed to be Y-shaped to increase the chance of contact with the OPC and funnel the connector into its chamber, reducing the time needed to complete the task. Moreover the valve is extended outwards to prevent other mission-specific tools from blocking the tool from retrieving the OPC.

Figure 34 One way valve cross section render

SWINGING MULTIPURPOSE HOOK

The Swinging Multipurpose Hook (SMH) is a hook used to retrieve both mesh catch bags and eel traps and is mounted on the corner SMS rail. A neodymium magnet is attached to the hook, allowing it to be retracted when not hooked onto anything. When a weight, such as a mesh catch bag or eel trap is put onto the hook, it will swing to a 90-degree angle, preventing the weight from leaving the hook. The force of the magnet can be adjusted using a screw which pushes the hook away from the hinge, allowing the tool to be tuned to the weight of mesh catch bags and eel traps.

Figure 35 Opened SMH

EXTENDER

The extender is a tool designed to retrieve sediment samples located deep inside pipes and is mounted inside the bottom frame of the ROV. A brushless motor attached to the side of the measuring tape's shell drives a small gear that turns a transfer gear in a 1:4 ratio. The transfer gear turns another internal gear attached to the spool in another 1:4 ratio, resulting in a final gear ratio of 1:16, which provides enough force to extrude the tape. A piece of Velcro is attached to the tip of the measuring tape on a small sled to retrieve the sediment sample. The sled has a curved surface which prevents the tool from getting stuck on the corrugated walls of the tube. A bearing is integrated in the center of the spool to reduce friction generated during rotation. Small extrusions on the measuring tape shell further reduce the surface area and friction with the gears.

Figure 36 Render of Extender

ROBOTIC PARALLEL GRIPPER

The Robotic Parallel Gripper (RPG) is a linear claw designed to transfer coral fragments, install mesh catch bags and reconnect the new power connector. It could also be used as backup in case other tools fail. The RPG is mounted on the vertical corner rails and accompanied by 2 cameras looking above and underneath it to maximize pilot visibility and ease in using the tool.

The brushless motor on the center gripping surface of the RPG drives a small gear, which turns a pair of larger gears that are connected to two threaded blocks at a 1:3 gear ratio. The gears rotate the threaded blocks thus articulating the gripper. Two linear rods are used for rigidity and strength. This is further aided by rails and guides flanking the claw's gripper surfaces. These moving surfaces feature interchangeable attachments for different use cases and tasks.

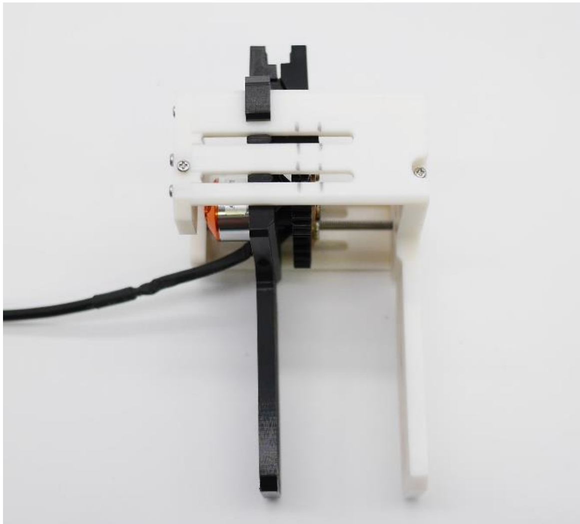

Figure 37 Opened Robotic Parallel Gripper

MESH CATCH BAG DROPPER

The mesh catch bag dropper is attached to the Bi-Electromagnet and holds the mesh catch bag when the electromagnet is turned on, swinging open to deploy when the tool is turned off. It consists of 2 parts: the upper part, which is secured to the top and the front side of the Bi-Electromagnet using M5 screws, and the lower part, which is connected to the upper part by a hinge. The bottom part has a washer which connects to one side of the Bi-Electromagnet. The mesh catch bag is mounted in the rectangular space between the 2 parts. Foam is also glued to the adjacent corners of the rectangular space to hold the mesh catch bag tightly and prevent it from swinging or moving during mission runs, thus allowing easier placement of mesh catch bags onto the Seabin. A slight slope on the rectangular space allows the mesh catch bag to slide out easily when being deployed.

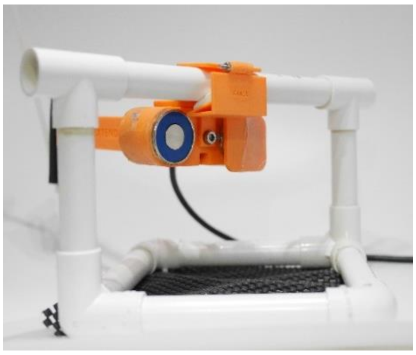

Figure 38 Mesh Catch Bag Dropper holding mesh catch bag

BUILD VS BUY

Delta strives to build and fabricate parts in-house which allows designs to achieve unique functions. The decision of purchasing parts instead of developing in-house partially depends on the fabrication capability of the team members, as well as if a well-developed version of the component is already available for purchase on the commercial market. Components that exceed this capability, such as cameras, are purchased, although these components are usually modified in-house after purchase.

Usually, components are thoroughly researched to ensure that it is commercially purchasable. In the case that the component is commercially available, the function, cost, and feasibility along with the reliability of that component are taken into consideration.

The team may also do post-market modifications if the product lacks the needed functionality. One example is the thruster produced by Blue Robotics that Delta uses. In order to integrate the ESC and CAN capability, Delta modified the housing and embed all electronics into the thruster.

NEW VS REUSED

Delta strives for innovations that bring improvement to all aspects of the ROV. The decision on whether parts should be reused depends on the required functions, the effort of fabrication, financial cost and the reliability of the new component. This means that most of the parts used on the ROV are brand new, including electronics such as thrusters and EMs. However, the universal hubs and power tether mounted on the Sashimi are used parts from Fish Logic's Blazin' Hydra ROV as it is compatible with the electrical systems and power consumption of Sashimi.

SAFETY

SAFETY RATIONALE

Delta always places safety as its number one priority no matter the cost. Therefore, the team aims to make Sashimi and their operation protocols safe for personnel when they operate it or perform maintenance on it. Protecting the environment is also taken into heavy account when designing the ROV to prevent it from harming wildlife and affecting the local geography.

To ensure safety for personnel during operation, a set of protocols and rules are made to prevent accidents from occurring. Proper poolside protocols and function of tools are briefed to team members before handling, and swapping tools on the ROV are regularly practiced to identify and avoid mishaps. Team members are also encouraged to give feedback on protocols and communicate issues to each other during poolside operations to come up with solutions. Tasks are delegated to the most suitable members to ensure that every person knows what they need to do during all stages of the operation.

When emergencies do occur, team members are aware of and follow protocols to ensure the safety of themselves, the ROV, the environment and the wildlife. An example of this is when the ROV malfunctions underwater, a kill switch is used to prevent harming wildlife near it and Sashimi is carefully brought back if the situation is dire. The capability to understand what to do during difficult circumstances allows for a safe and efficient operation period.

SAFETY FEATURES

A series of safety features are added on the ROV and the control box to prevent accidents and dangers from happening. These safety features include:

Thruster shrouds	A pair of 3D-printed thruster shrouds are installed on each thruster to prevent fingers from approaching the propellers. This reduces the chances of injuries caused by propellers.
Notification LED	A notification LED is added on all electrical modules to show that those modules are functioning properly.
No sharp edges	No sharp edges exist on the ROV, since all edges are chamfered or filleted to prevent cuts and injuries.
Handle	A handle is installed at the top of the ROV, allowing it to be carried with one hand and managed at a safe distance
Fast blown fuse	A fast blown fuse is used to cut the power when the current exceeds the limit of 25A to prevent overloading wires and the system
Kill switch	A kill switch is added on the control box to cut out power in the case of emergency situations

SAFETY PROCEDURES

Workshop Safety

A list of safety procedures are used in the Delta workshop to ensure the safety of team members. Cables and tools are placed accordingly to reduce tripping hazards and dangerous items such as flammable liquids are placed separately to reduce risk of fire. Ventilation and safety equipment such as goggles and gloves are also used during soldering or resin handling to prevent injuries or toxic fumes from harming the body.

Operation Safety

During ROV operation, all members are well informed about their tasks and responsibilities to prevent any miscommunication or injuries. When the ROV is resurfacing and members of poolside are in contact with it, the hands of the pilot are not allowed to touch the joystick to prevent any poolside members from being hurt by a moving ROV. Power is also cut from the ROV when electrical components need to be switched out or tools are being swapped to prevent electrocution. Team members by the poolside are constantly alert and ready to push the kill switch during an emergency situation and tools are carefully placed to prevent tripping or stepping on sharp objects.

Logistics

When transporting tools and props, fragile components are surrounded by packing foam to prevent damages from occurring and creating sharp objects, harming team members when handling them. Also, when moving heavy objects, team members use proper posture by lifting with hips and knees to prevent spraining or straining of muscles.

Covid Safety

Due to Covid restrictions, masks are constantly worn in the workshop to prevent the spread of diseases. Social distancing measures of 2 meters are also kept in place to prevent the travelling of viruses, along with hand sanitizing or washing when entering the workshop.

TESTING AND TROUBLESHOOTING

Testing tools and systems on the ROV is extraordinarily important as it ensures that Sashimi is reliable and its tools function as expected. The first stage of testing in Delta is dry testing. Tools are tested on land to confirm that their mechanisms and associated software are functioning normally. These tools are then taken to a kitchen sink to verify water tightness is achieved and that water does not affect their functionality. An inflatable pool is later set up to prove the tool's usability and compatibility with Sashimi, while the pilot gives feedback regarding the tools and potential improvements. Finally, a water trial proves the tool's consistency, and that it is adaptable to the operation program.

However, if any issues arise during the testing such as pilot dissatisfaction, water penetrating epoxy castings and contacting electronics or unreliable mechanisms, the tool is instantaneously revoked and new ideas or solutions are brainstormed by the team to meet the end of the current Sprint Cycle. When Delta attempts to find a solution to the problem, extensive research and investigation is first done to identify the issue such as points of water entry or faulty tolerances in parts. A solution is brought up during daily meetings and completed by team members responsible for the task. The testing cycle is repeated after improvements are made to the tool.

FINANCES

BUDGET PLANNING

Our primary source of income is from the FDCT. They provided Delta with generous funding for our project. Some other sources of income include our school, Macau Anglican College, and our parents. When Delta looks for materials, we look for different suppliers and compare the price, functionality and the quality of the product. We then differentiate and choose the best alternative to save costs while maintaining a high quality product.

Table 1 Project budget table. (All currency in HKD)

School Name:	Macau Anglican College	**Reporting Period:**	From:	07/01/2020
Instructor:	Andy Tsui		To:	30/06/2021
Team Name:	Delta			
Income				
Source				Amount
FDCT Grant				$30,000.00
Macau Anglican College Grant				$10,000.00
Expenses				
Category	**Type**	**Description/Examples**	**Projected cost**	**Budgeted Value**
Hardware	Re-used	Joystick	$ 350.00	$ 350.00
Hardware	Purchased	Waterproof plugs and general electrical components	$ 6,000.00	$ 6,000.00
Hardware	Purchased	Blue Robotics thrusters	$ 6,560.00	$ 6,560.00
Hardware	Purchased	3D Printer filaments	$ 4,000.00	$ 4,000.00
Hardware	Purchased	General mechanical parts	$ 5,000.00	$ 5,000.00
Sensors	Purchased	Task specific sensors	$ 4,000.00	$ 4,000.00
Total Income				$ 40,000.00
Total Expenses				$ 25,910.00
Total Expenses-Re-used/Donations				$ 2,350.00
Total Fundraising Needed				$ 3,640.00

COST ACCOUNTING

School Name:	Macau Anglican College	**Reporting Period:**	From:	03/07/2020
Instructor:	Andy Tsui		To:	31/03/2021
Team Name:	Delta			

Date	**Type**	**Category**	**Expense**	**Description**	**Amount**	**Running Balance**
10/07/2020	Purchased	Hardware	Electromagnet		$ (200.00)	$ (200.00)
11/07/2020	Purchased	Electronics	ESC		$ (500.00)	$ (700.00)
12/07/2020	Re-used	Electronics	Tether	Power, Signal Cables	$ (400.00)	$ (1,100.00)
13/08/2020	Purchased	Hardware	Ballast Ball	25mm Steel Ball	$ (50.00)	$ (1,150.00)
14/08/2020	Purchased	Hardware	Hex Rod	Aluminum 7mm Hex Rods	$ (100.00)	$ (1,250.00)
15/08/2020	Purchased	Hardware	PLA+ Filament	3D Prints	$ (1,000.00)	$ (2,250.00)
16/09/2020	Purchased	Electronics	Camera		$ (210.00)	$ (2,460.00)
17/09/2020	Purchased	Hardware	Waterproof Plug		$ (500.00)	$ (2,960.00)
18/10/2020	Purchased	Hardware	T100 Thruster		$ (4,800.00)	$ (7,760.00)
19/10/2020	Purchased	Hardware	Foam	PU Foam	$ (100.00)	$ (7,860.00)
20/11/2020	Purchased	Electronics	Motor Driver		$ (30.00)	$ (7,890.00)
21/11/2020	Purchased	Electronics	CAN Controller	Custom PCB, Beetle	$ (500.00)	$ (8,390.00)
28/11/2020	Sales	Funds	Key Ring Fund Raising	Open day sales	$ 1,600.00	$ (6,790.00)
07/12/2020	Cash Donation	Funds	FDCT Funding		$ 10,000.00	$ 3,210.00
22/12/2020	Purchased	Hardware	PVC Pipes	Props	$ (300.00)	$ 2,910.00
23/12/2020	Purchased	Hardware	Silicon Grease	For waterproofing	$ (50.00)	$ 2,860.00
24/04/2021	Purchased	Hardware	Epoxy	2 Part AB Epoxy	$ (200.00)	$ 2,660.00
25/04/2021	Purchased	Hardware	Permanent Magnet		$ (30.00)	$ 2,630.00
27/06/2021	Purchased		Team shirt		$ (1,200.00)	$ 1,430.00
Total Raised						$ 11,600.00
Total Spent						$ 10,170.00
Final Balance						$ 1,430.00

Table 2 Cost accounting table. (All currency in HKD)

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ACKNOWLEDGMENTS

MATE II - Competition organizer

FDCT - For generous funding

Macau Anglican College - For generous funding

Mr Andy Tsui - Our mentor for advising the team

Mr Ryan Ip - Our mentor in supervising resource purchases and conducting experiments

Ryan Chan - For teaching and advising our team

Fish Logic - For assisting and providing support

Joshua Ho, Yorky Sin, Gavin Chan and Cerys Chan - For mentoring, assisting and providing support

DSEDJ - For provision of water testing sites

TOPIX - For sponsoring our team shirts

In Lab:

- Safety gear is worn depending on the performed task
- No tripping hazards are in the vicinity
- All positions of dangerous and sharp objects are known
- Work area is safe and cleared
- Make sure a supervisor is watching
- Masks and hand sanitizers are used

Soldering:

- Good lighting
- Proper ventilation is used
- Safety goggles and gloves are used
- Work area is cleared

Handling Resin:

- Gloves and masks are used
- Proper ventilation is used
- Work area is cleared
- Table is covered with a disposable surface
- Tissue is prepared

ROV Retrieval:

- Commander calls out "ROV resurface"
- Poolside members call out "ROV on surface"
- Pilot keep hands off of controller
- Call out "Retrieve ROV"
- Retrieve ROV from water

Loss of Communication:

- Restart ROV
- Restart control program
- If reconnected, continue with mission

Maintenance:

- Verify that thrusters are no longer moving and is not tangled to any foreign objects
- Check for any cracks or visual damages
- Check that all cables are managed
- Check that all plugs are tight
- Check that all screws and nuts are tight

On Deck:

Setting Up on Deck:

- Area is safe (no tripping hazards, sharp objects or exposed electricity)
- Tether is laid out
- Plugs are filled with silicone grease
- Power switch is off
- Thruster shrouds are on
- No wires are exposed
- No screws or nuts are loose
- Tether is secured to the ROV
- Tether has proper strain relief
- 25A fuse is used

Power-Up:

- Ensure ROV and poolside members are ready
- Call out "Power on"
- Turn on power
- Run control program
- Call out "System test"
- Perform system test
- Verify video feeds are working
- Test active manipulators
- Adjust placements depending on pilot preferences

Launch:

- Call out "ROV ready"
- Poolside members call out "ROV Ready"
- Call out "ROV launch"
- Launch ROV