SPIDA

Technical Documentation

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I. Abstract

Over-Defined is a company dedicated to developing the most advanced ROV to conquer challenges while performing complicated and perilous underwater missions. Twenty-two dedicated and skilful engineers had been working for over 450 hours, creating the new multi-functional ROV, Spida. Our third generation ROV. It is designed to be state-of-the-art in ROVs and aims to observe the ocean, understand our world, and create a better future.

To fight against the toughest situation in the water, Spida is equipped with a pair of precisely controlled grippers, 8 powerful brushless motors, a heavy-duty load attachment hook(HLAH), 4 HD cameras, and a rotary actuator. These advanced designs enable our ROV to perform complicated tasks such as recovering a multi-function node, deploying smart cable, saving underwater species, etc. An additional vertical profiling float is designed along with the ROV to assist the ROV in investigating the underwater environment.

In this document, we will talk about Spida's design and our development process throughout the year. By contributing to the ROV development, we strive for a better future, understanding and protecting our planet with our passions and knowledge.

Figure 1. Company Photo

II. Project management

A. Company Profile

Over-Defined is a three-year-old company located in Kwun Tong, Hong Kong. Our company specializes in designing robots that protect and restore ecosystems and biodiversity. Currently, we have an all-male workforce comprising 22 dedicated engineers, divided into three departments: Mechanic, Electrical, and Software.
All engineers at Over-Defined have multiple responsibilities, including completing documentation, brainstorming ideas, and constructing the robots. Our engineers have extensive experience in ROV and land-based (mini-robocon) competitions. Each department is led by a senior engineer who mentors and guides the junior engineers.
The CEO of Over-Defined takes on two roles within the company: managing the team's progress and serving as the head of the Mechanic department. Additionally, the CFO oversees the company's expenses and fulfills the role of the Electrical department. Furthermore, the CTO also acts as a member of the Mechanic team. The CEO and CTO work closely together to conduct testing and provide feedback to the engineers, aiming to improve the design and functionality of our robots. Their collaboration allows for faster testing and ensures the delivery of reliable components.

Over-Defined experienced a 4.8% increase in the number of engineers this year. As part of their onboarding process, all new engineers underwent a one-year comprehensive learning course, which covered a wide range of knowledge and skills in Mechanical, Electrical, and Software domains. This initiative was implemented to ensure that the engineers have a solid foundation in these areas, enabling them to contribute effectively to the company's long-term growth and ensuring their success in the future.

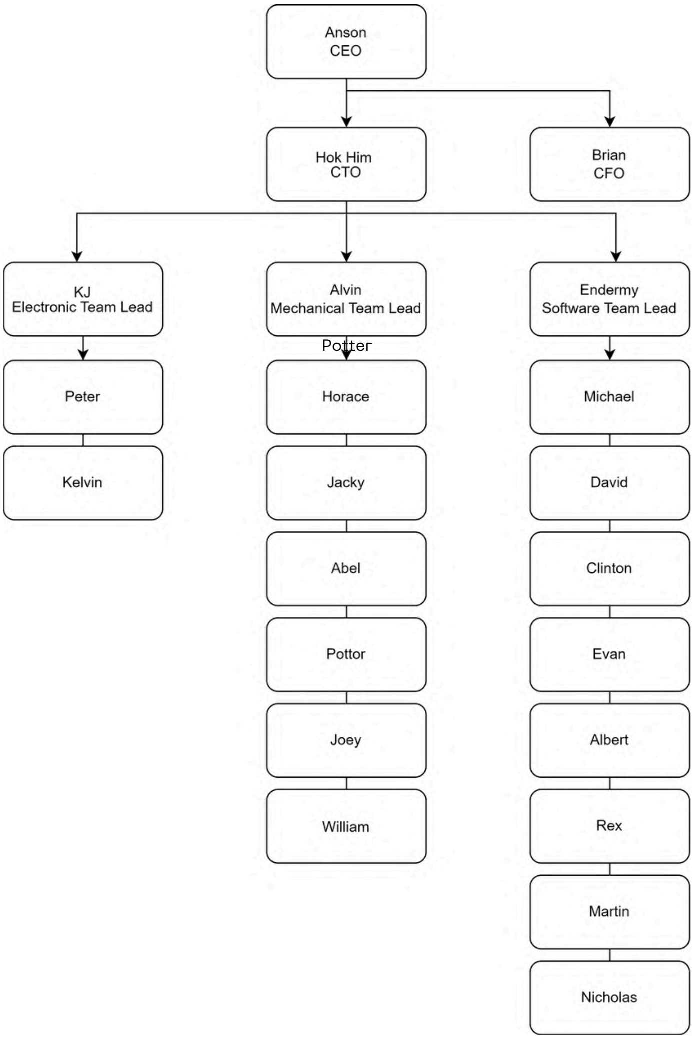


Figure 2. Over-Defined Company Distribution Diagram

B.Scheduled Project Management

Over-Defined follows a Scrum development method, shown in Figure 3, in each development task to shorten the development time needed and maximize the cost-effectiveness of designing the system.

We will have our sprint planning before each holiday to create a scrum target. After that, we will have a scrum review of what we did during the holiday and our performance during the sprint. By implementing the scrum development method, we can utilize as much working time as possible.

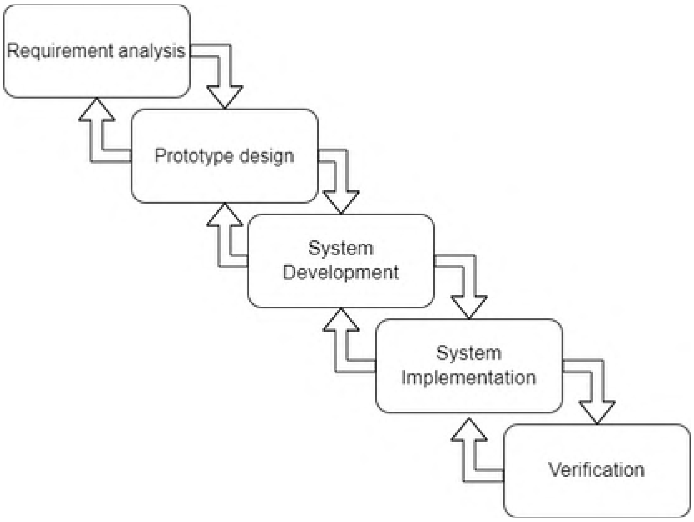


Figure 3. Waterfall development per task

Starting from September, the team meets every Wednesday, Friday and Saturday as these schedules are mostly free for our team. We created a work distribution table (Figure 4) for engineers to remind them what tasks they are required to do. Usually, the CEO, CFO and other team leaders will use additional time to have some meetings to track progress and make plans for the upcoming Wednesday and Saturday.

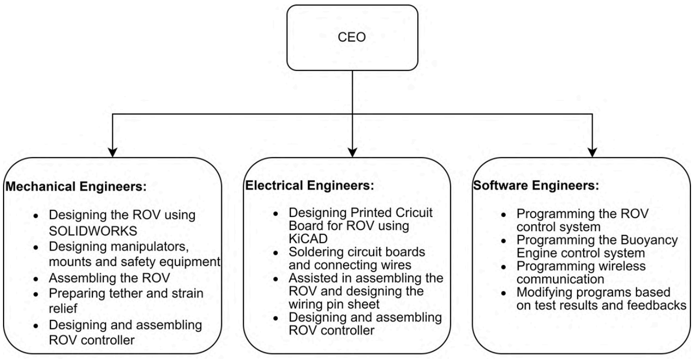
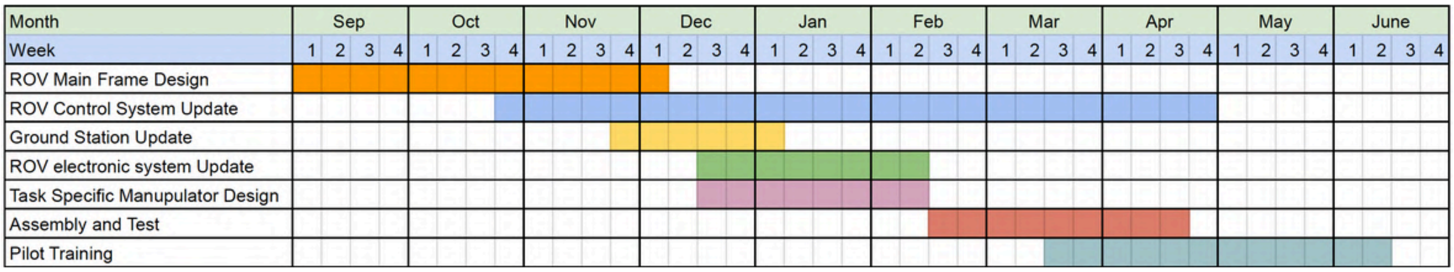


Figure 4. Work distribution

Additionally, We have also designed a year-long schedule (Figure 6), and engineers will update it over time when they finish a task. The team utilised the Gantt Chart to assign and manage tasks, set timelines and keep track of our time management, so the task would be done on time.

Figure 5. Engineers working at the lab together



Month	Sep				Oct				Nov				Dec				Jan				Feb				Mar				Apr				May				June			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ROV Main Frame Design	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧																											
ROV Control System Update								🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦								
Ground Station Update												🟨	🟨	🟨	🟨	🟨	🟨																							
ROV electronic system Update															🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩																		
Task Specific Manupulator Design															🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪																		
Assembly and Test																							🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥									
Pilot Training																											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		

Figure 6. Project Timeline

III. Design Rationale

A. Mechanical

1. Frame Design

Enhancing Spida is one of the major priorities for our company. We improved the ROV's frame by focusing on its functionality and performance.

Understanding the importance of an all-rounded design, we keep our knowledge updated and learn from the past. This year, we aimed to improve Spida's water resistance and functionality.

After evaluating different frame designs, we chose the octagonal-shaped frame for this year’s competition, shown in Figure 7. Due to its octagonal design, this greatly reduces the water resistance as there are large holes in the design to let water go through them. This also increases stability when compared to our past ROVs.

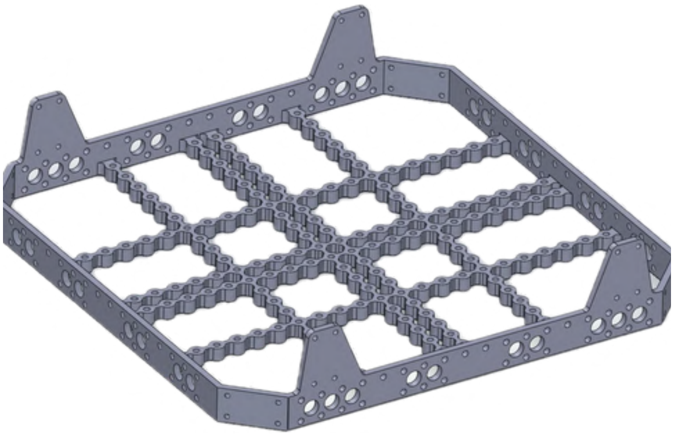


Figure 7. Prototype of octagonal frame

But, we soon found out that the frame faced difficulties when it came to the installation of thrusters. In the prototype, the thrusters were placed too high, which could make the centre of gravity of the ROV too high, causing the ROV to be unstable. This is why we made a trade-off in the final version of the frame. We reduced the number of holes for installing manipulators to make the installation of thrusters lower. Additionally, We also changed the placement of the thrusters on the side to make it easier to be installed.

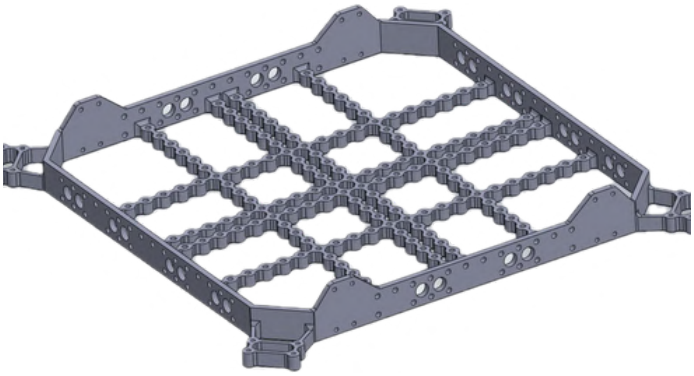


Figure 8. Final Version of octagonal frame

Regarding Spida's functionality, one prominent aspect of the design is the numerous standardized holes on the side of the frame. These holes are designed to facilitate the installation of off-the-shelf products such as LEGO and MakeBlock components. This allows for easy customization and additional equipment or systems integration onto the ROV.

2. Gripper

The gripper is one of the most important components of the ROV. To increase the sturdiness and agility of the gripper, we chose to use Polylactic Acid (PLA) to print the gripper. We designed two multi-functional grippers to complete the tasks given. The reason why we adopted 3D printing is that it gives us more options for customization and is more cost-efficient than purchasing pre-built grippers from the market. Numerous modifications have been made during the design process to optimize the gripper for the best performance in competition.

Each side of the gripper is powered by a GDW IPX6 waterproof brushless servo. The servo can exert up to 45 kg/cm of force. The high output of force ensures the gripper does not loosen easily when holding heavy loads and can complete tasks smoothly.

Most tasks can be done with the gripper, which includes special features that suit our needs. For example:

Diamond Clamps: Capable of clamping objects in different sizes. It can complete tasks such as pulling pins and returning the failed recovery float to the surface.
Acoustic Release Pin Puller: Insert the hook to "Trigger" the release of the multi-function node's recovery float.

Figure 9. The Installed Gripper

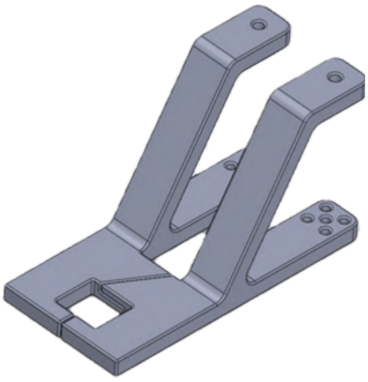


Figure 10. V20 Gripper

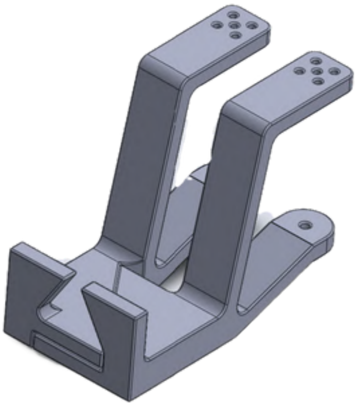


Figure 11. V50 Gripper(Final Version)

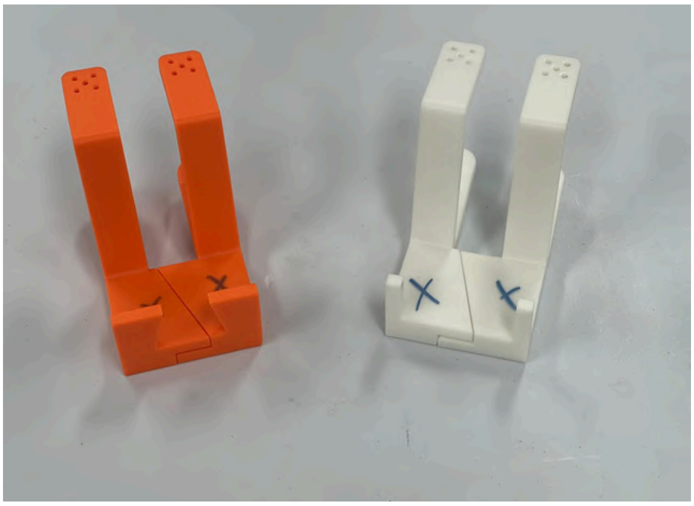


Figure 12. Past Printed Versions of the Gripper

3. Hook

We have designed a hook specifically for the purpose of placing the irrigation system in the designated area. The hook serves the purpose of securely holding the irrigation system, enabling the gripper to easily lift and position the sprinkler. This solution not only saves time but also does the task more efficiently and easily.

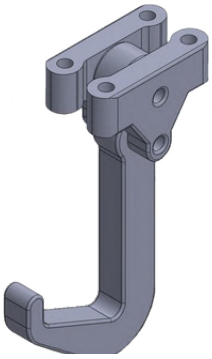


Figure 13. The Hook

4. “Steering Wheel”

We have opted to utilize a 360-degree servo and a specialized tool called the "Steering Wheel" to perform the task of turning the irrigation system. The “Steering Wheel” is designed as a cylinder-shaped extension that incorporates Lego bricks, allowing us to activate the irrigation system easily. We chose Lego bricks for their ease of use and the flexibility they provide in making corrections or modifications if any issues arise during the process.

Figure 14. The “Steering Wheel”

5. Camera

The model of camera we chose to use on the ROV is an Analog High-Definition camera (AHD) with a 195° field of view. The camera provides us with great visibility in the water and assists the pilot when manoeuvring the vehicle. Additionally, We installed 4 cameras on the vehicle and they are located on top of each manipulator to assist the pilot in doing tasks easier.

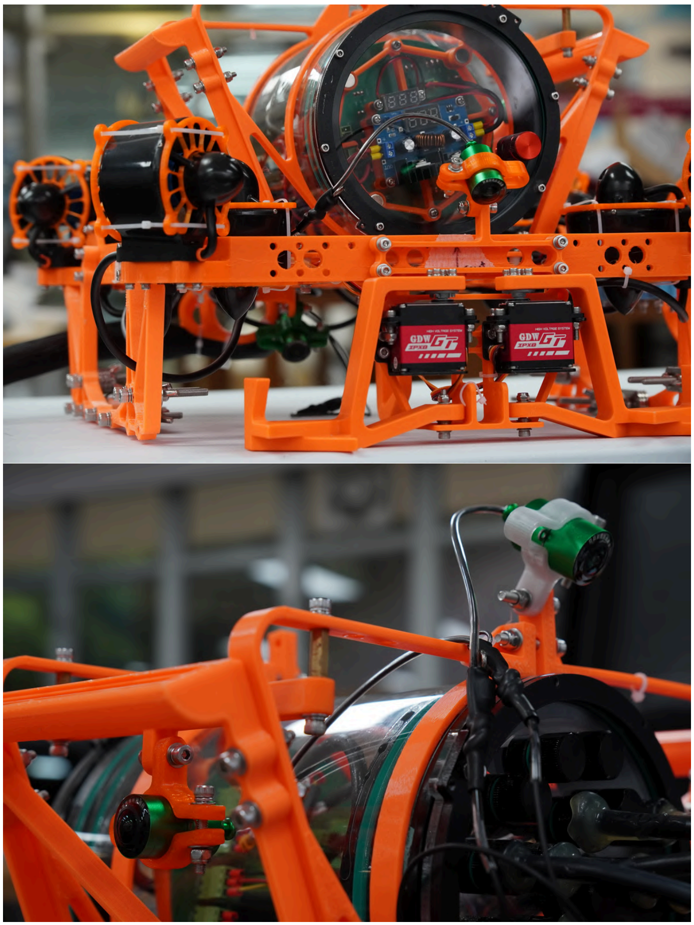


Figure 15. Placements of Cameras

6. Stone Clamp

We found out that picking up rocks the most efficient way is to design a clamp underneath the robot, therefore, we created a clamp that can pick up the rocks easily. Additionally, the clamp is opened and closed by a slider at the ground station.

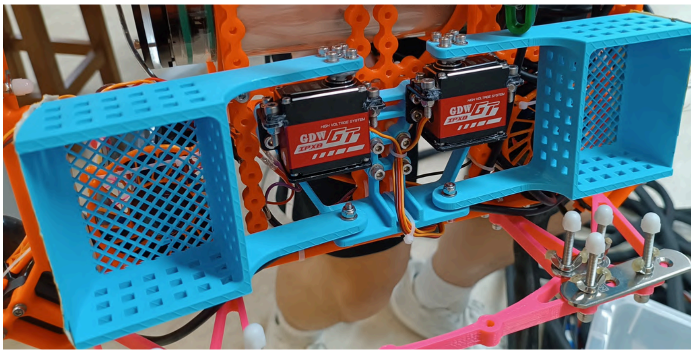


Figure 16. Stone Clamp

7. Temperature Probe

We have installed a temperature probe capable of detecting underwater temperatures. It is connected to a 20-meter wire, allowing it to transmit the temperature data to an LCD display located at the ground station.

It is used to measure the temperature to check the SMART cable sensor readings.

Figure 17. Temperature Probe used

8. Recovery Line Attachment

Our company has neglected the use of the carabiner provided by MATE. Instead, we have designed our 3D-printed part that can lock in the U-bolt once entered. Once the bale is pushed through the entrance of the part, the entrance will be closed by itself using the tension of a rubber band, leaving the U-bolt stuck in the interior; creating a 360-degree wrap around the bale.
The recovery line is attached to the carabiner right before the procedure. The claws will be used to carry this part by holding its handle.

Figure 18. Recovery Line

9. Design and Fabrication

We mainly used 3D-printed parts to create our ROV. There are a lot of advantages when using 3D-printing technology.

Compared to laser cutting, we do not have to remove materials when making the parts, especially when manufacturing the thicker parts in some areas. For example, if we use subtractive manufacturing, we need to remove a lot of materials if we need to create taller areas(Figure 19). 3D printing is additive. It builds objects layer by layer from the ground up, which minimizes waste as it only uses the material necessary to form the object.

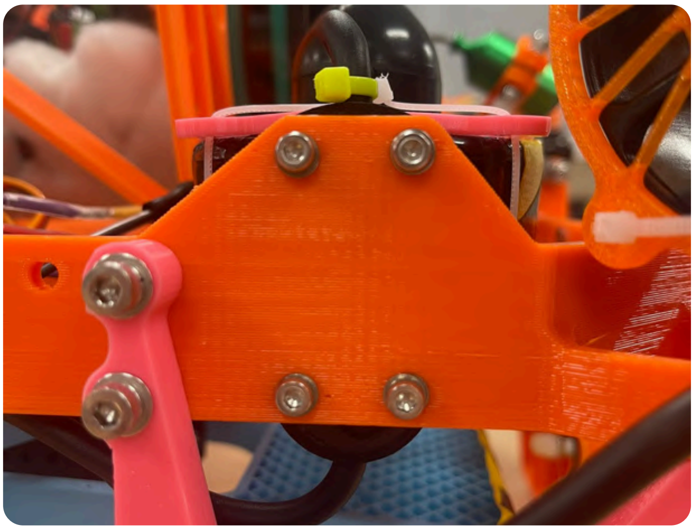


Figure 19. Taller areas on the side of the ROV

Compared to laser cutting, 3D printing can print vertical and horizontal holes in one part, while laser cutting cannot. For example, thrusters are needed to be installed in vertical holes. Therefore, we used 3D printing to print the frame in one piece.

Figure 20. Vertical holes on the side of the ROV

B. Electrical

1. Centralized circuit board

The centralized circuit board (Figure 21) is designed for the ROV, ground station, and vertical profiling float. This allows a high level of customization, enabling the integration of components with varying pin spacing onto a singular board. Compared to our previous solution of using prototype boards, this design accommodates the installation of components with different pin spacing.

Another point on using centralized circuit boards is the enhancement it brings to wiring clarity and maintenance efficiency. By embedding exterior wiring into the circuit board's internal wiring, the overall electrical system can achieve an organized structure.

Moreover, this circuit board can serve as a centralized connection point, allowing easier installation. With two power plains featuring different voltage options, components can be seamlessly embedded onto the same board without the need for separate boards. This consolidation simplifies the assembly process and promotes a more compact and efficient system design.

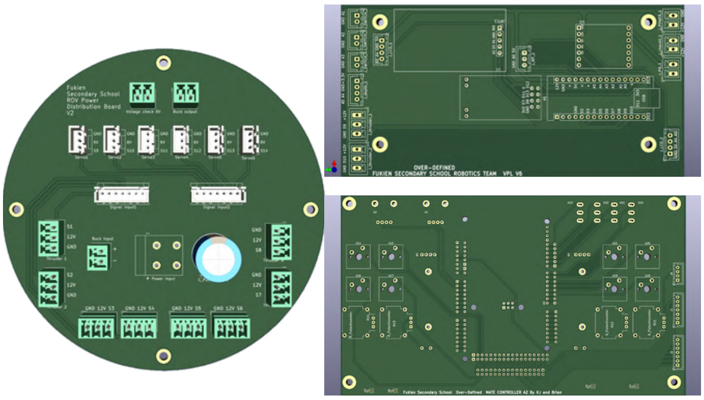


Figure 21. PCB

2. On board voltage monitor

The inclusion of a voltage monitor (Figure 22) on both the ROV and vertical profiling float introduces a valuable tool for efficient debugging and monitoring.

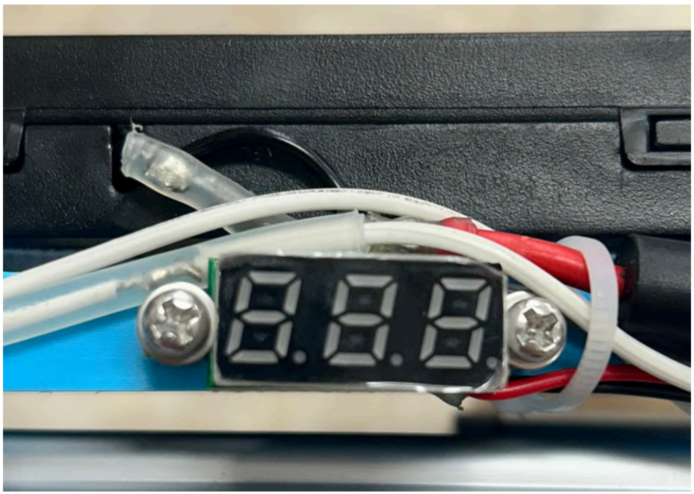


Figure 22. Voltage monitor

3. On board voltage regulator

The voltage regulator serves as a crucial intermediary between the power source and the components on the ROV and vertical profiling float that operate at lower voltages. Stepping down the voltage from 12 volts to 6 volts. The regulator ensures that the connected components receive the required voltage level for their optimal performance.

C. Software

The goal of our software is to enable unrestricted underwater movement which is controlled by the pilot.

To accomplish this goal, we utilize the Arduino platform and C/C++ as the programming language. We control the robot by using a mathematical formula that calculates the angle of the joysticks and maps to the corresponding thruster while mapping potentiometer values to the gripper and a 360-degree angle servo.

In addition, we included a switch in the controller that can change the mode of the ROV's thrusters. This feature allows us to maximize the usage of the power of 25A, by dynamically adjusting the thruster speed. By doing so, we can minimize the time required to complete tasks, thus improving the ROV's efficiency.

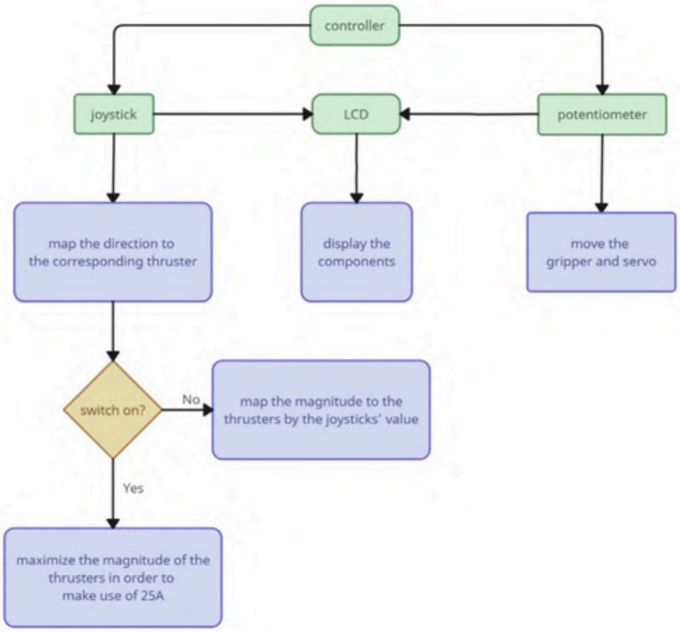
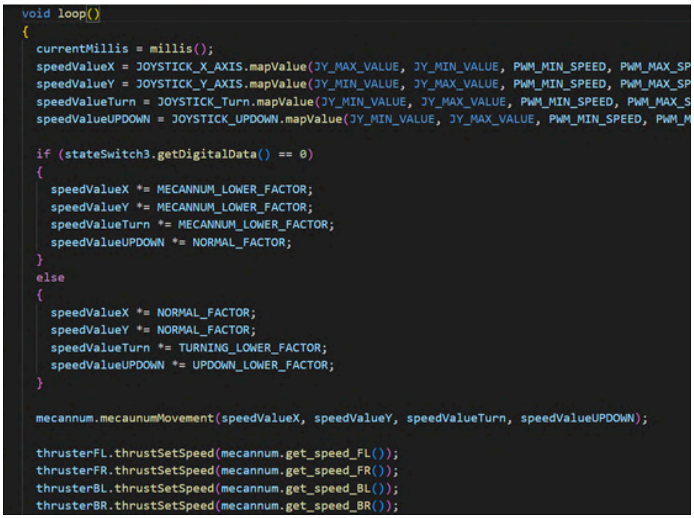


Figure 23. A flow chart detailing the operation of the ROV

We installed an LCD on the controller that displays all of the parameters in real-time so that it can significantly decrease our debugging time, enabling us to address problems swiftly and effectively when there is something wrong with the robot.

Before we write the program, we will think of a flow chart (Figure 23) of what we need and how to control the robot. Making a flow chart makes our thinking clearer and doesn't mess up easily.

Example of programs:



```
void loop()
{
  currentMillis = millis();
  speedValueX = JOYSTICK_X_AXIS.mapValue(JY_MAX_VALUE, JY_MIN_VALUE, PWM_MIN_SPEED, PWM_MAX_SP
  speedValueY = JOYSTICK_Y_AXIS.mapValue(JY_MIN_VALUE, JY_MAX_VALUE, PWM_MIN_SPEED, PWM_MAX_SP
  speedValueTurn = JOYSTICK_Turn.mapValue(JY_MIN_VALUE, JY_MAX_VALUE, PWM_MIN_SPEED, PWM_MAX_S
  speedValueUPDOWN = JOYSTICK_UPDOWN.mapValue(JY_MIN_VALUE, JY_MAX_VALUE, PWM_MIN_SPEED, PWM_M

  if (stateSwitch3.getDigitalData() == 0)
  {
    speedValueX *= MECANNUM_LOWER_FACTOR;
    speedValueY *= MECANNUM_LOWER_FACTOR;
    speedValueTurn *= MECANNUM_LOWER_FACTOR;
    speedValueUPDOWN *= NORMAL_FACTOR;
  }
  else
  {
    speedValueX *= NORMAL_FACTOR;
    speedValueY *= NORMAL_FACTOR;
    speedValueTurn *= TURNING_LOWER_FACTOR;
    speedValueUPDOWN *= UPDOWN_LOWER_FACTOR;
  }

  mecannum.mecaunumMovement(speedValueX, speedValueY, speedValueTurn, speedValueUPDOWN);

  thrusterFL.thrustSetSpeed(mecannum.get_speed_FL());
  thrusterFR.thrustSetSpeed(mecannum.get_speed_FR());
  thrusterBL.thrustSetSpeed(mecannum.get_speed_BL());
  thrusterBR.thrustSetSpeed(mecannum.get_speed_BR());
```

24. Program Code for ROV

```
unsigned long currentTime, elapsedTime;
int UpDownCount;

CRGB leds[NUM_LEDS];
Interface lcd(20, 4, false);

Transmitter radio(PIN_CE, PIN_CSN);
DepthSensor sensor;

BouyancyEngine pusher(MOTOR_DRIVER_DOWN, MOTOR_DRIVER_UP);
Digital switch_UPDOWN(PIN_SWITCH_UP_DOWN, INPUT_PULLUP);
Digital switch_MANUAL_AUTO(PIN_SWITCH_MANUAL_AUTO, INPUT_PULLUP);
Digital switch_ESTOP(PIN_SWITCH_RESERVE, INPUT_PULLUP);

void setup()
{
  FastLED.addLeds<WS2812, LED_PIN, GRB>(leds, NUM_LEDS);
  Serial.begin(9600);
//  Wire.begin();
  lcd.init();
  sensor.init();
  radio.init();
```

Figure 25. Program Code for Vertical Profiling Float

D. Innovation

The biggest innovation this year is creating the Vertical Profiling Float (Figure 26), as it was our first time using a buoyancy engine to power the NRD. During our testing, we faced a couple of challenges. Since NRD will change the inner pressure of the buoyancy engine, the enclosure may pop due to the pressure difference. Therefore, we have to adjust the pressure of the enclosure to be neutral when the piston is retracted and negative pressure when the piston is fully extended. To avoid positive pressure without affecting the NRD's normal functionality.

3D printing enables unique ROV designs by creating custom components. LEGO's standardized hole dimensions allow integration with 3D-printed parts, enhancing versatility. This technology empowers the exploration of the underwater world with creativity and streamlined functionality.

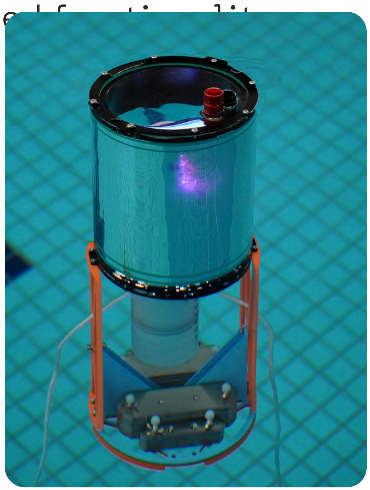


Figure 26. The Vertical Profiling Float

E. Problem-solving

Our team set up a Gantt chart, for greater insight into the deadlines and progress on different tasks. All members are required to record their progress by filling out a progress log, which helps team managers keep track of the progress of different tasks and have a better overview of things, making management easier and more efficient.

Organizing meetings (Figure 27) online and in person can allow better communication between teammates, without having time crashes. This saves more time and improves our working efficiency.

Figure 27. Meeting

F. Design process

Our team members started designing the ROV by selecting the ROV's objectives from the tasks. We discussed the solutions and planned the design after understanding the task. Many meetings were held and teammates could express their ideas freely for better improvements on each component of the ROV. Different prototypes were made and the functionality of the components was tested (Figure 28) until we found the best solution for the tasks.

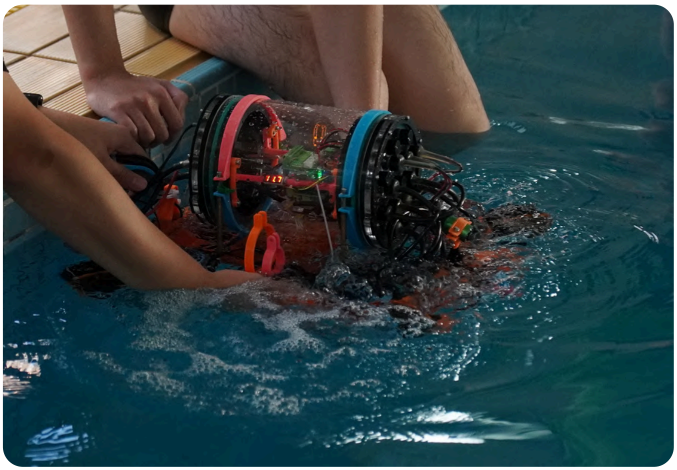


Figure 28. Testing

G. Build VS Buy

While we have the chance to improve our ROV, we must make a budget to avoid overspending. If we acquire prebuilt parts in the market, we may lack funds to buy other necessary items.

The frame of our ROV is entirely designed by ourselves. This enables us to build an ROV that can fulfil our requirements, including high mounting flexibility and low centre of mass.

While buying existing parts can save development time, designing our parts increases the flexibility of our design. To increase efficiency when doing the tasks, we can optimize the parts to specific tasks. Some of the tasks cannot be finished with existing prebuilt parts, so we need to design the manipulators on our own.

There is equipment that we do not have the skills to make on our own, like monitors and cameras. We try to compare the options available in the market and find the ones that best suit our needs. For example, We bought a monitor that is much brighter than others so we can see the images clearly on a sunny day.

H. Testing protocol

To optimize the speed and efficiency of our ROV, our team formulated a meticulous procedure to thoroughly test the ROV for errors or defects following its construction. In case of any breakdowns or water leakages during the process, we promptly halt the protocol and swiftly address the issue to prevent further damage. This protocol has proved that it can enhance and improve our ROV, enabling us to achieve our goals more swiftly than in previous builds.

Within our testing protocol, we first put the ROV into the pool to inspect the ROV for any signs of water leakage or malfunction. Once the ROV successfully passes these checks, we proceed with the testing phase by performing tasks (Figure 29). These include utilizing the ROV grippers to retrieve objects, testing the maximum distance the ROV can travel before signal loss, and conducting a thorough assessment for any damages or minor water leaks.

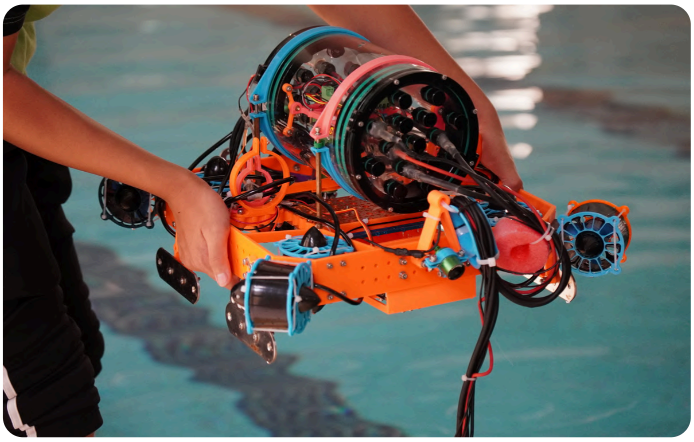


Figure 29. ROV testing

I. Propulsion

We configured the thrusters with a design shown in Figure 30, as we believe this would help the ROV reach its full potential. According to research conducted by our mechanical engineers, our ROVs with this design enable us to manoeuvre it in all six degrees of freedom. It can also have the same speed in every direction. But, the trade-off is that we couldn't utilize the whole six degrees of freedom, we can just utilize degrees of freedom because there is no micro-controller unit in the watertight compartments, therefore we can't add a gyro into the compartments, and the manoeuvrability got limited.

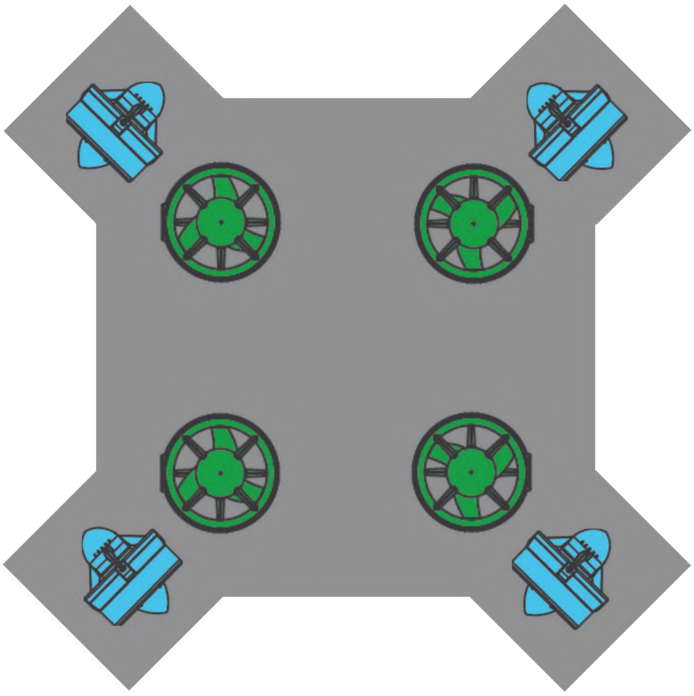


Figure 30.
The placement of the thrusters

J. Buoyancy and Ballast

Achieving neutral buoyancy was a key design priority for the ROV. We discovered that the waterproof enclosure had significant buoyancy, so we incorporated stainless steel weights to balance it out. These weights were strategically distributed along the sides of the ROV to maintain equilibrium. By utilizing these additional weights, we could finely tune the buoyancy to achieve a slightly positive balance. This deliberate design choice ensures that the ROV can effortlessly rise to the surface and be recovered even in situations where power is unavailable.

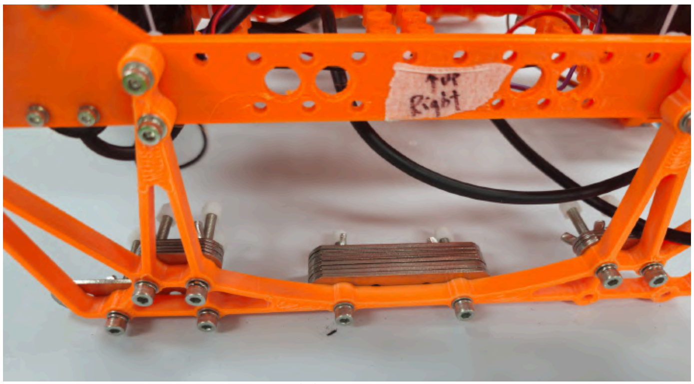


Figure 31. Ballast used on Spida

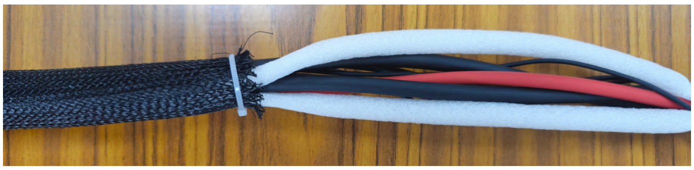
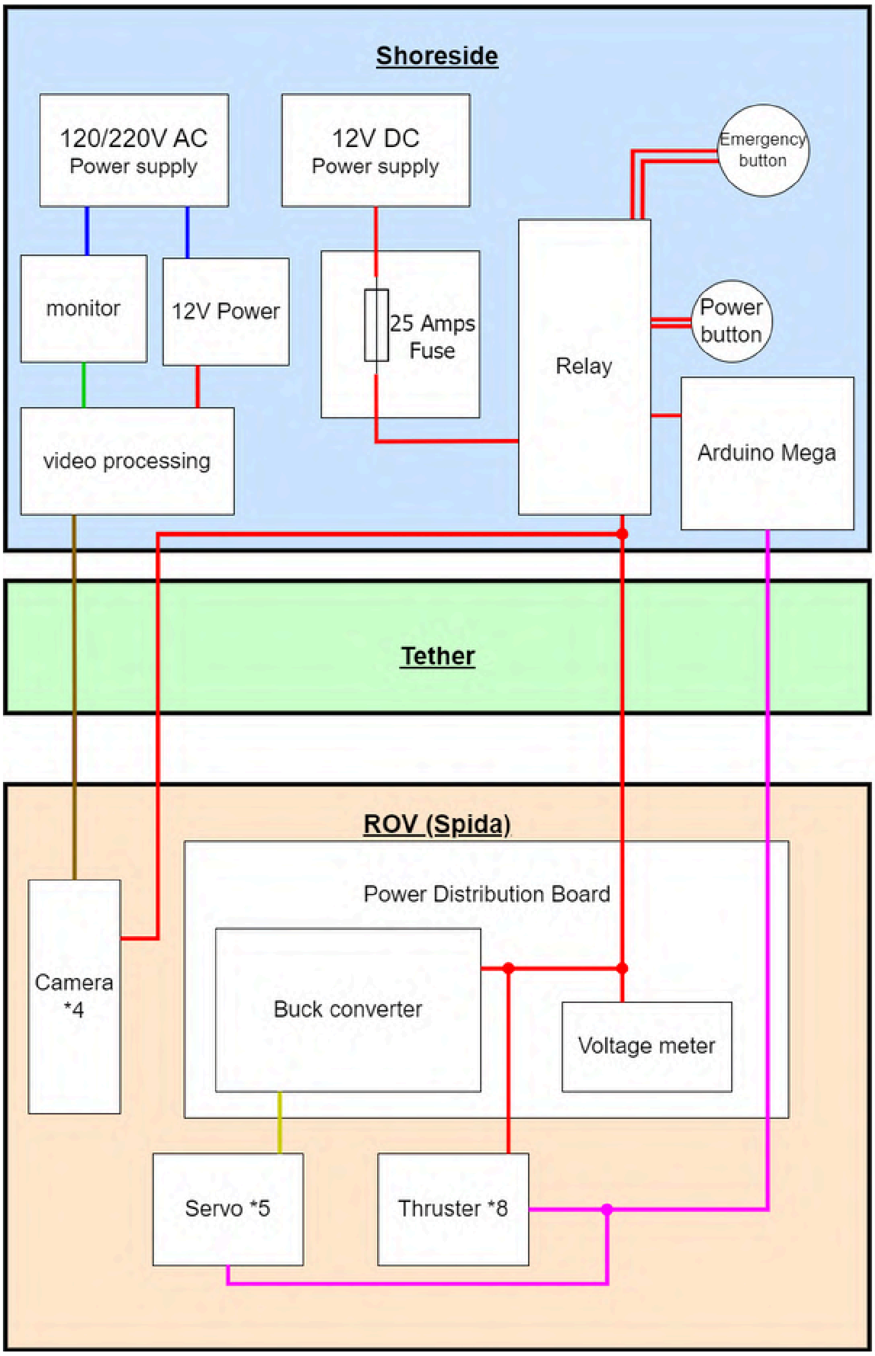


Figure 32.
Buoyancy foam inside the tether

IV. SID



Fuse calculation:

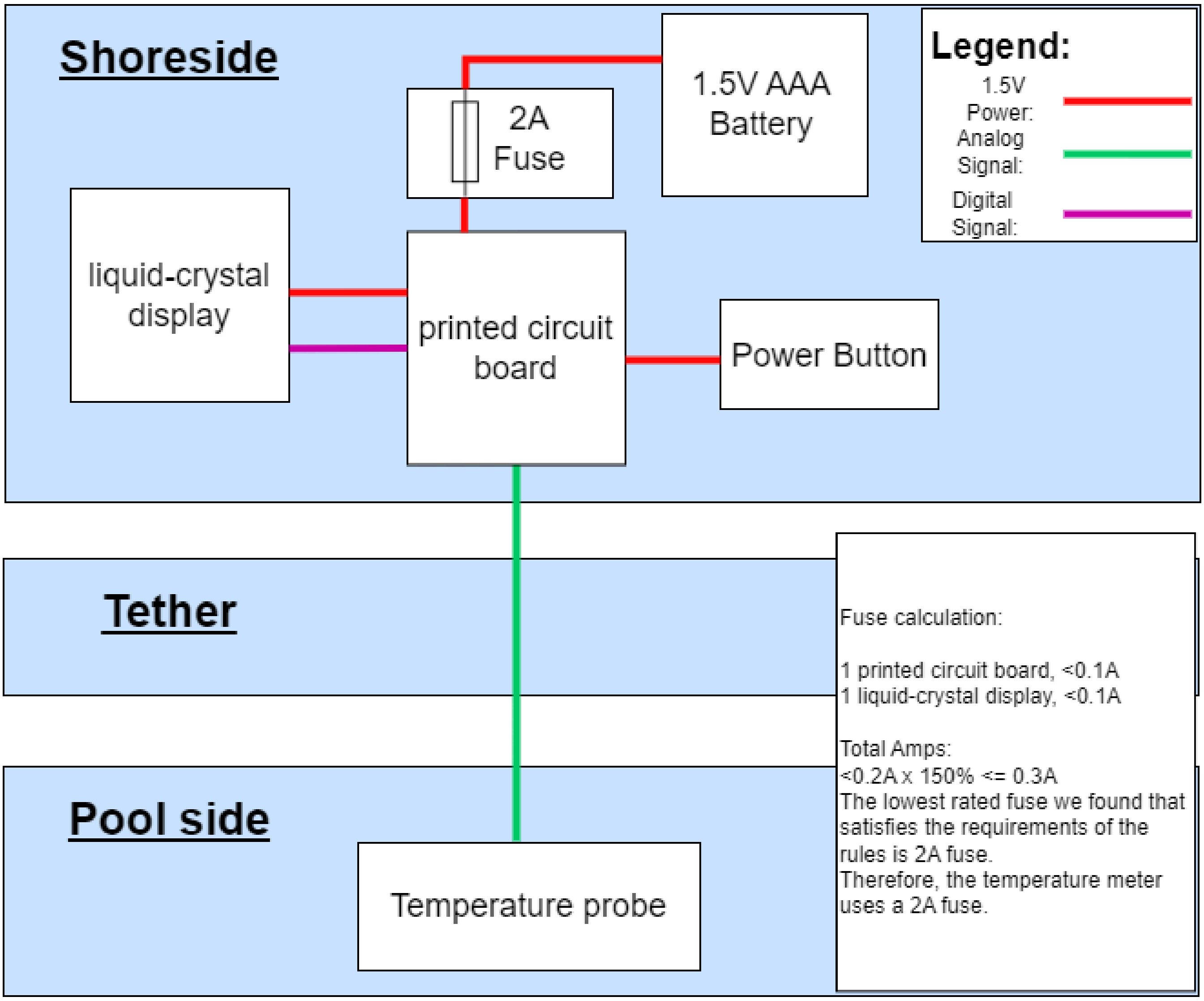
8 Thruster (1.5A each)	total 12A
4 Cameras (0.67A each)	total 2.68A
5 Servos (1.2A each)	total 6.0A
1 Arduino Mega (0.05A each)	total 0.05A

Total Amps:
20.73A x 150% ~31.095A
Therefore, ROV uses a 25-AMP fuse.

Legend:

12V DC power:	🟥
5V DC power:	🟨
120/220V AC Power:	🟦
HDMI:	🟩
Camera signal:	🟫
PWM signal:	🟪

Figure 33.
Spida SID



Fuse calculation:

1 printed circuit board, <0.1A
1 liquid-crystal display, <0.1A

Total Amps:
<0.2A x 150% <= 0.3A
The lowest rated fuse we found that satisfies the requirements of the rules is 2A fuse.
Therefore, the temperature meter uses a 2A fuse.

Figure 34.
Temperature meter SID

V. Safety

A. Philosophy

Safety is always the highest priority of our company. Therefore, to maintain a safe and comfortable working environment for the public and our engineers, Over-Defined implemented rigorous safety policies in different aspects. We ensure all our employees have sufficient skills before working to prevent accidents from happening. All members must be trained to use dangerous tools to ensure the safety of individuals.

B. Safety Protocols

To make sure that the safety of our employees is as secure as possible, we need to take a sufficient amount of safety measures like safety goggles when machining, soldering, or working with the ROV. Gloves, masks, and ear plugs are required to operate tools and handle certain materials and machines while working in the lab.

For storage, every toolbox is labelled according to its contents to make searching for components less demanding, every tool has to be stored in the corresponding container after usage to prevent accidents, reduce clutter, and provide an overall safer and more efficient working environment.

All engineers have to attend safety training for equipment before attempting to make use of it, especially for tools that are sharp or heavy to minimize the occurrence of accidents.

Overall, these measures are essential to contributing to a safe and productive environment for everyone involved.

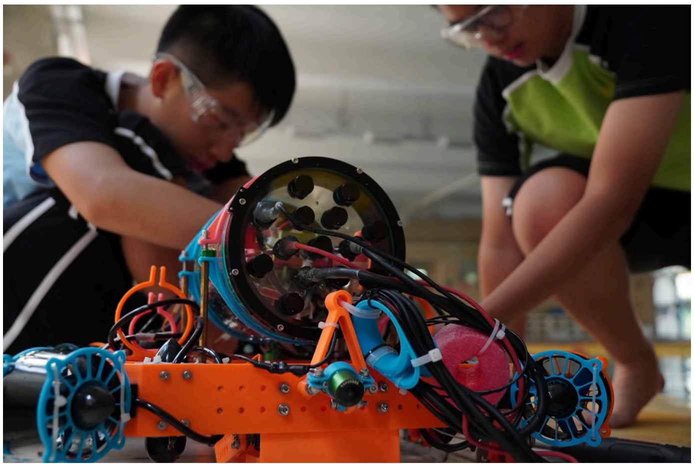


Figure 35. Reparation of the Robot

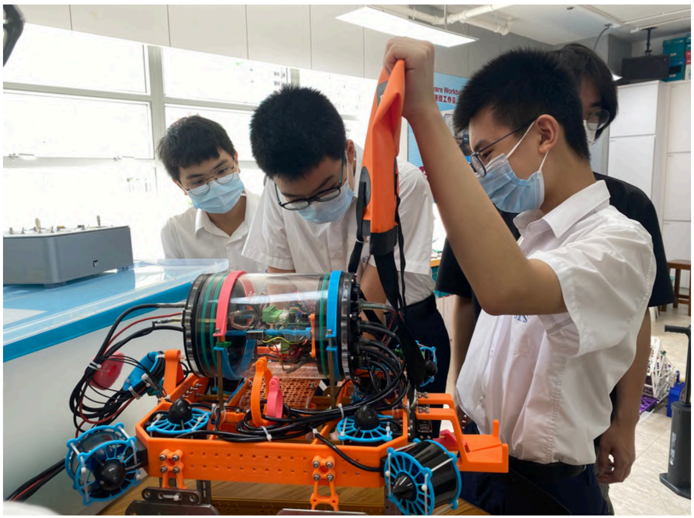


Figure 36.
Investigation of the Robot

Figure 37.
Over-Defined Engineers soldering

C. Mechanical Safety Features

The primary objective of implementing mechanical safety measures is to safeguard our ROV from potential damage. To achieve this, our company has incorporated strain relief features on both the ROV and its tether to prevent the controller from getting dislodged and the cables from pulling the ROV. Additionally, we have utilized the fillet feature in SOLIDWORKS to smooth the corners and edges of our 3D prints, ensuring that the ROV does not have any sharp or hazardous edges. prints, ensuring that the ROV does not have any hazardous edges.

Moreover, we have developed thruster protectors that reduce the potential damage to the ROV's thrusters. It significantly decreases the chances of the ROV enduring any damage.

Figure 38. Thruster Guard

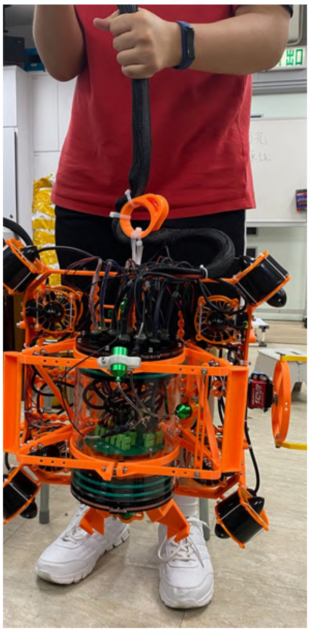


Figure 39.
ROV with Strain Relief

D. Electrical Safety Features

In order to ensure that the ROV's power supply is immediately cut off in case of issues, we have connected a 25-amp fuse and an emergency button to a normally open relay in our control box. When a problem arises with the ROV, we will press the emergency button to prevent the ROV from receiving power.

The camera monitor operates utilizing a 220/110V AC connection to an SDI camera multiplexer, which is equipped with a 220/110V AC to DC power supply. The AC and DC power supplies are distinctly separated and labelled to prioritize the safety of our ROV’s power supply and to mitigate any potential wiring errors. These precautions are in place to facilitate secure and efficient operations.

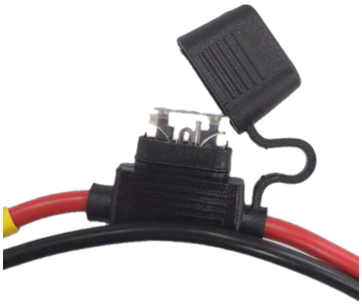


Figure 40. Fuse

VI. Testing and troubleshooting:

We conducted tests on the ROV in the swimming pool that Fukien Secondary School provided, which enabled us to identify potential issues in new versions of components and significant changes to the ROV. These tests provided valuable insights for the team on how to improve the ROV.

After finding problems, we continuously strive to enhance and update our design to ensure optimal performance of the ROV. Through thorough testing and analysis, we have identified areas where improvements can be implemented to further enhance efficiency and durability. Our team is committed to pushing the boundaries of innovation and consistently refining our design.

Figure 41. Testing ROV in Pool

VII. Budget and Cost Projection

We have developed a comprehensive budget plan to secure funding for the development of our ROV project. The majority of the budget has been allocated to electronics and mechanical parts. Regarding electronics, a significant portion of the funds has been utilized for the procurement of cables, tethers, digital cameras, and a waterproof case. As for hardware components, a substantial portion of the cost has been dedicated to the construction and manufacturing of the ROV. The remaining portion of the hardware budget has been allocated for the purchase of tools and materials such as servos, thrusters, and 3D-printing filaments.

To promote efficient spending and sustainable resource utilization, we conducted a thorough review of materials from previous projects. We explored possibilities for reusing tools and parts through proper maintenance and upgrades. After carefully summarizing expenses, the total expenditure on our project amounts to HKD10,676, remaining within the allocated budget of HKD12,000. For further information on the financial aspects of the Spida project, including budget projections and a detailed cost breakdown, please refer to Appendix A and Appendix B.

VIII. Challenges

Throughout the development process of our ROV, we encountered numerous challenges that required significant investment of time, resources, and effort to overcome. Two critical hurdles were weight management and maintaining proper buoyancy. Addressing these challenges involved multiple iterations, investments in high-strength materials, and extensive testing to achieve the desired balance.

Another challenge we faced was cable management. Ensuring the safety of the ROV and preventing tangles or damage necessitated clear labelling, organization, and routing of all wires and tethers. By implementing effective cable management strategies, such as utilizing cable ties, cable trays, and dedicated cable channels or compartments, we were able to maintain order and facilitate troubleshooting.

To tackle the cable management challenge, we employed cable protection sleeves to encase and secure the wires, effectively keeping them in place. In addition to the aforementioned challenges, we encountered conflicts in developing a robust yet reconfigurable design, optimizing power efficiency, creating intuitive controls with high visibility, managing costs, adapting to diverse environments, improving reliability, and meeting regulations. Overcoming these conflicts required innovative solutions and careful trade-offs to ensure the successful development of the ROV.

IX. Lesson learned

Our team learned how to overcome various obstacles together through discussions and evaluations. When we encounter technological issues, we proactively search for related information online and find more reliable and efficient ways of solving the problem. For example, we found a better sealing method and had group discussions to come up with a suitable solution. Due to the intense school work, we sometimes have a lack of time, so we needed to manage our time between making our ROV, Spida and our studies. We came up with a timetable which helped us to manage our time properly and make sure that not a second was wasted. We may have had different opinions during discussions, arguments were raised during the whole preparation for the competition. So, in the process of discussing, we learned how to cooperate with our co-workers efficiently.

Moreover, we learned how to respect the opinions of others and incorporate them to create better solutions. In the process of making the props, we also learned how to accurately measure the length of each tube and be careful when cutting. Safety regulations are needed to prevent unnecessary injuries.

X. Future Improvements

Project Management

There is room for improvement in our project management, mostly about time management in the process. For now, the time length of our meeting might be overrun by minutes and become a waste of time since the flow of the meeting is not well organised. Therefore, we plan our meeting beforehand and squeeze our extra meeting time into the production of our ROV. It will help us achieve better management in task distribution, boosting productivity and performance.

Design Process

At the moment, there are some areas of potential improvement regarding our ROV. To smoothen the operation of ROV, We can discuss our ideas concerning different parts on a regular basis. By working in closer collaboration, our team can integrate members' opinions and therefore boost the efficiency of the designing process.

XI. Acknowledgements:

Over-defined is incredibly grateful for the support of the following organizations and individuals who have contributed to the development of Spida:

- Fukien Secondary School — for the continuous support, sponsorship, and resources
- HUNG Kam Fai and WU TING KWAN — our supervisors, for their consistent guidance in all aspects
- HUI Shek Hin, CHAN Kam Pui and LI En Yee Ian — our mentors, for their guidance and technical help throughout the development of Spida
- MATE Center — for organizing the 2024 MATE World Championship, providing a platform for the community to learn about marine technology, and promoting STEM education around the world by solving real-life problems
- The Institution of Engineering and Technology, Hong Kong (IET HK) — for organizing the 19th IET/MATE Hong Kong Regional of the MATE ROV Competition and educating the Hong Kong public on marine technology

XV. Appendix

A. Proposed Budget

Items		**$ (HKD)**
Mechanical and electronics:	ROV Frame	750
	Thrusters	3000
	Cameras	1000
	Sensor	750
	Waterproof Cabin	900
	Electronics	750
	ROV Controller	2400
Research and testing:	Mechanical	1100
	Electronics	1050
	Software	300
Total		12000

B. ROV Cost Projection

Item category	**Amount**	**New/ reused/ donated**	**Amount spent (HKD)**	**Market price (HKD)**
Serial peripheral interface (SPI)	1	New	32	32
Arduino mega	2	New	76	38
Servo	6	New	1680	280
24 inch monitor	1	New	1250	1250
Wire connecting terminals	60	Reused	120	2
DVR monitoring host	1	Reused	269	269
Tether	1	New	494	494
Camera	4	Reused	752	188
Waterproof cabin	1	Reused	450	450
Emergency button	1	Reused	29	29
Joystick	2	Reused	10	5
Thruster	10	Reused	2590	259
3D printed ROV frame	1	New	750	750
Wires	/	Reused	500	500
Electric parts	/	New	500	500
Tether foam float	1	New	34	34
Controller protection box	1	New	540	540
Detachable tether plug	15	New	300	20
Printed circuit board (PCB)	30	New	300	10
Total expenses				HKD 10676