Technical Documentation

Thuwal, Saudi Arabia

Red Sea Robotics Team

Emils Ekers	CEO
Dylan Todorov	CTO
Idhant Nag	Financial Analyst, Float Engineer
Reuben Potter	Head of Engineering, Mechanical Engineer
Xuan Wang	Outreach Coordinator
Irene Tempone	Head of Communications
Nitin Prabhu	Mechanical Engineer
M. Ahsan Jamil	Mechanical Engineer, Editor
Dean Todorov	Task Tool Specialist, Safety Officer, Editor
Pablo Finkbeiner Rivera	Mechanical Engineer
Jacob Kennedy	Float Engineer, Mechanical Engineer

Supervisors

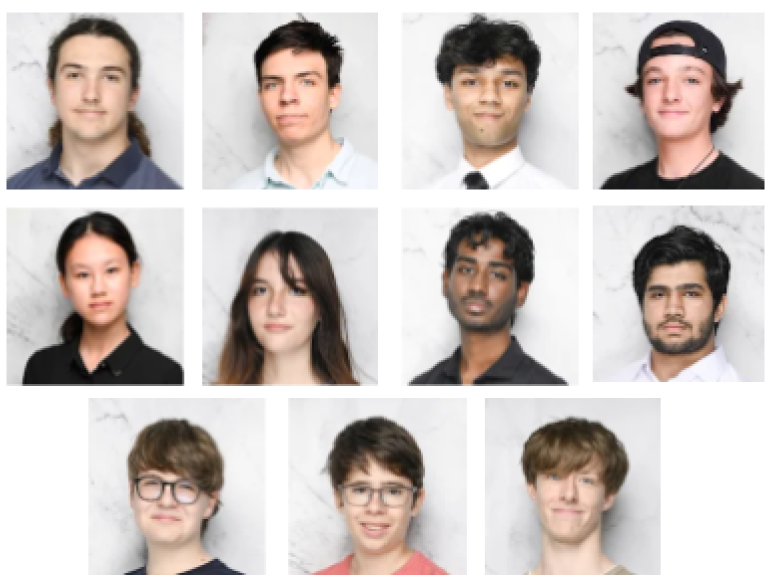
Mery Tellez & Pim Arora

Table of Contents

Abstract

Red Sea Robotics, a student-led underwater robotics team at The King Abdullah University of Science and Technology (KAUST) School, has been a collaborative force over the past two years. We have closely worked with various departments across KAUST—including the RISC Lab, the PCL Core Lab, CEMSE, the Provost's Office, the KEY Initiative, KCRI, the Prototyping and Product Development Core Lab—to design and engineer high-performance ROVS for the MATE ROV World Championship. Red Sea Robotics is proud to represent Saudi Arabia in this year's competition, continuing to showcase innovation and engineering excellence from the Middle East. We are proud to bring regional innovation to the global stage. Our unique position is a testament to our dedication and innovation, and we are excited to showcase our achievements worldwide. After two successful international appearances, our team is building *Tyrone IV*, the third-generation evolution of our underwater ROV series. Drawing on lessons from *Tyrone III*, our new ROV incorporates significant upgrades: a Newton Subsea Gripper Arm, a Raspberry Pi processor for improved onboard control, and two additional Blue Robotics thrusters for enhanced mobility.

Every design choice is backed by rigorous prototyping, testing, and engineering review. With 11 team members selected based on their strengths and interests, we operate as a cohesive unit. Our focus on efficiency, innovation, and safety ensures that we deliver high-performance ROVs that meet the highest standards. This technical documentation outlines our design evolution, build process, risk mitigation strategies, and financial planning.



Red Sea Robotics Team

Emils, Dylan, Idhant, Reuben, Xuan, Irene, Nitin, Ahsan, Dean, Pablo, Jacob

Project Management

Company Profile

Red Sea Robotics is based in Thuwal, Saudi Arabia. This is the third year Red Sea Robotics has participated in the MATE ROV after two successful years. The company comprises eleven members ranging from the ninth to the twelfth grade. This year, the team saw three additional members from the previous year. Members of the team are assigned to different roles, as listed below:

Emils Ekers Chief Executive Officer (CEO)	Manages task delegation and ensures timely completion of all team responsibilities.
Dylan Todorov Chief Technological Officer (CTO)	Manages technical aspects of the ROV, focusing on software and electronics. Develops ROV control systems, software, and debugging
Idhant Nag Chief Financial Officer (CFO)	Keeps track of costs, financial records, and seeks sponsors for the team.
Reuben Potter (Lead), Ahsan Jamil, Pablo F. Rivera, Nitin Prabhu Mechanical Engineer	Responsible for constructing ROV, including the frame and any physical aspects relating to it, such as sensors, machinery, and controllers.
Dylan Todorov (Lead), Jacob Kennedy Electrical Engineer	Assemble and test all electrical components that make up the ROV, including all circuits and equipment
Idhant Nag, Pablo F. Rivera, Dylan Todorov, Jacob Kennedy Float Engineer	In charge of designing and manufacturing the float device.
Dean Todorov Safety Officer	Ensures safety throughout the creation of the ROV, establishes safety regulations and prevents any potential accidents
Ahsan Jamil, Dean Todorov Editor	Supervise and write documentation, and ensure completion before due dates
Xuan Wang Outreach Coordinator	Manages Red Sea Robotics' social media outlets, promotes the team, and acts as a representative during events.

Irene Tempone
Head of Communications

Liaisons with supervisors and other teams to coordinate suitable meeting times and to show progress

Scheduling and Planning

The Red Sea Robotics team met twice weekly on Tuesday and Wednesday, dedicating 5 hours weekly to building the Tyrone IV at the Prototyping and Product Development Core Lab (IFL) in KAUST. The editor has made a Gantt Chart after having a final agreement with the team on how all events should be met, as seen in **Figure 1**. The Gantt Chart is planned ahead of time in terms of deadlines so that the team can get an overview of what to complete within the timeframe and to allow extra time in case an obstacle comes their way. This ensures that the team meets deadlines and understands what needs to be started and completed by the estimated deadline. Beginning in mid-October, the team worked on frame sketches and prototyping to determine the best fit to align with the MATE ROV regulations. Subsequently, the team continuously met the tasks set by the CEO, who regularly updated the protocols weekly so the team members could adhere to deadlines. The strict deadline will ensure the team will be on track to build the Tyrone IV efficiently.

Figure 1: Red Sea Robotics Project Timeline

Red Sea Robotics uses a structured communication and file-sharing system to ensure smooth collaboration and time management. Daily communication takes place over WhatsApp, allowing team members to coordinate meeting times, update each other on availability, and make quick decisions in real-time. This flexibility has helped the team adapt to changing schedules and maximise productivity during lab sessions. The team relies on Google Drive as a centralised platform for documentation and resource management. All essential files,

Figure 2: Parts Delivered

including technical documents, design iterations, safety protocols, and mentor feedback, are stored and organised in shared folders that are accessible to team members and mentors. Ahead of the 2025 build season, the team carefully reviewed the 2025 MATE mission video and engaged in detailed discussions to determine the parts and systems needed for *Tyrone IV*. A comprehensive shared parts list was created and finalised in December to align with the Gantt chart timeline, ensuring all components were ordered in time to meet key build milestones. By January, most parts had arrived at the lab and were ready to be assembled into the frame, as seen in **Figure 2**.

Design Rationale

Engineering Design Rationale

Our design process began with extensive prototyping to develop a frame that aligns with the MATE mission objectives. One critical constraint was maintaining a total ROV weight under 25 kg. To meet this goal, the engineering team selected a precision-cut aluminium beam system for the frame. These beams are lightweight yet durable, and their pre-drilled hole pattern allows for high versatility when attaching components. This modularity enables us to quickly reconfigure the frame during testing phases, similar to how LEGO pieces connect, greatly enhancing our ability to iterate on the design.

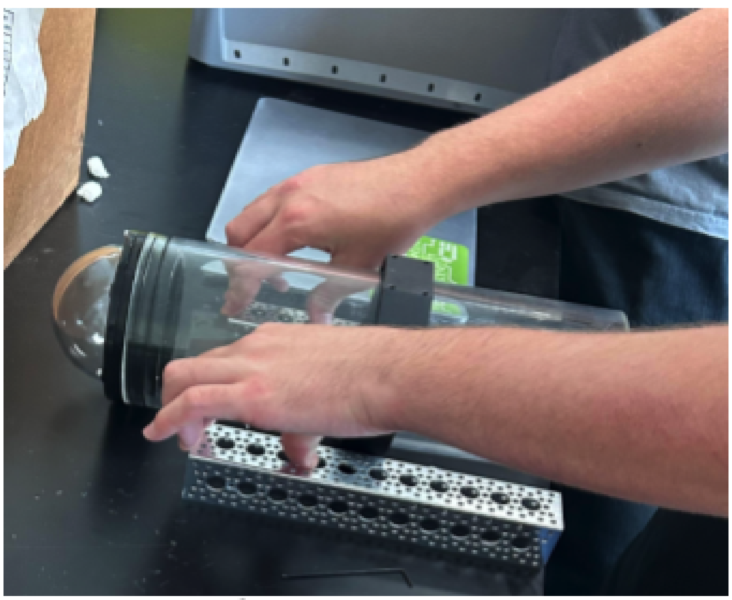


Figure 3: Initial Frame Brainstorming

The aluminium framing system used was partially salvaged from our previous ROV, *Tyrone III*, promoting sustainability and cost-effectiveness. However, several recovered parts had degraded bolt holes, leading to structural instability. These components were either replaced or supplemented with custom 3D-printed parts designed by the mechanical engineering team to maintain rigidity and precise alignment. The frame also incorporates laser-cut acrylic panels, which serve both structural and protective purposes. The integration of these materials creates a hybrid system that is both robust and adaptable.

Motor placement was another essential consideration in our design. The team determined that using two parallel aluminium frame sections provided optimal support and stability for thrusters positioned around the ROV's perimeter, as shown in Figure 3. This configuration enhances manoeuvrability and contributes to balanced buoyancy, discussed further in the Buoyancy and Ballast section.

Furthermore, key components such as the T200 Blue Robotics thrusters are fully compatible with our aluminium framing system, simplifying installation and maintenance.

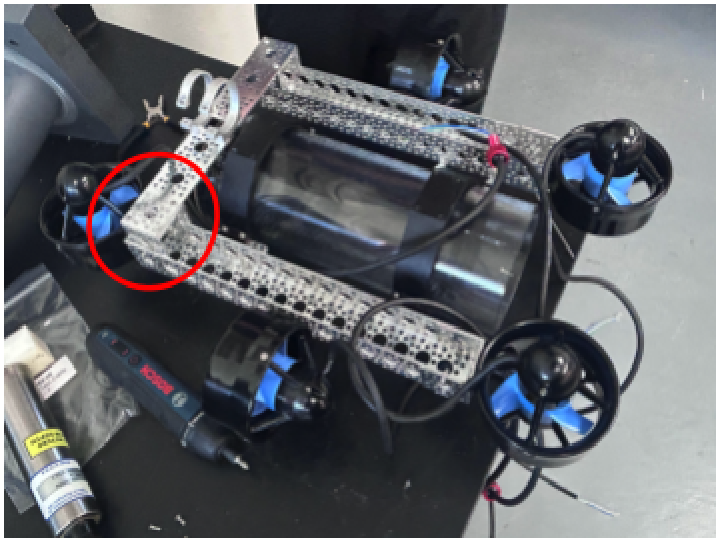


Figure 4: New Addition to *Tyrone III*

To ensure Tyrone IV can effectively perform underwater mission tasks, the mechanical engineering team strategically mounted the gripper arm holder beneath the watertight enclosure, as indicated by the red circle in Figure 4. This placement was chosen to provide an optimal field of view for the onboard camera, allowing pilots to manipulate objects with precision during tasks such as Mission Tasks 1, 2, and 3, which all require moving, retrieving, or repositioning underwater items.

Originally, the gripper arm was mounted onto a small box-shaped aluminum component. However, during testing, it became evident that this structure lacked the necessary stability and rigidity to support the gripper arm under load. In response, the team redesigned this section using a longer and wider aluminum frame integrated into the foundation of the ROV. This modification significantly improved the arm's stability and torque capacity, enabling it to lift heavier objects more reliably.

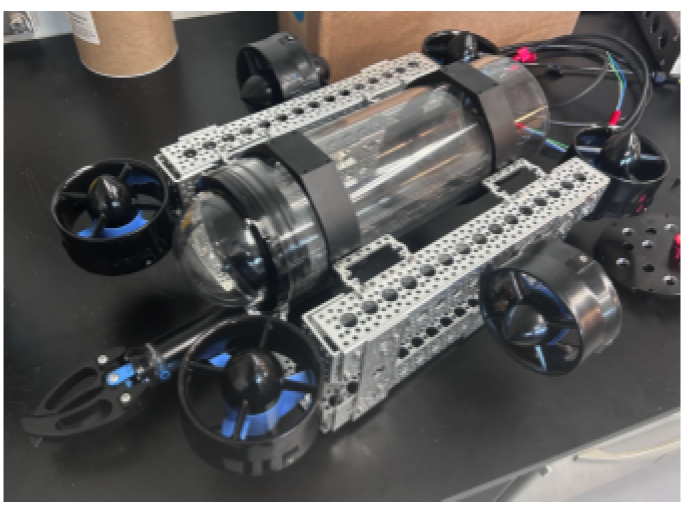


Figure 5: Gripper Arm + Frame Structure

Positioning the gripper arm below the watertight enclosure and aligned with the camera also enhances pilot visibility, which is essential for precise control during mission execution. This is particularly important for Mission Task 1.2, which requires precise navigation and manipulation of Smart Buoys. Pilots can accurately measure and assess objects underwater by ensuring the camera has a clear view of the gripper arm's activity, maximising the potential score for this task.

In addition to the structural changes made to support the gripper arm, Red Sea Robotics made further system-wide improvements to enhance the ROV's performance and reliability. The capsule penetrator was replaced following a failed leak test using vacuum pressure testing to ensure the integrity of the watertight enclosures. Safety guards were added to minimise the risk posed by sharp edges along the frame. Finally, the Raspberry Pi system was thoroughly troubleshooted and stabilised to ensure smooth communication and operation during all mission phases. The trade-offs are further discussed in the Vehicle Structure, Systems & Systems Approach

Figure 6: Final Tyrone IV for Regional Competition

Innovation

Red Sea Robotics continuously seeks improvements as it believes Tyrone IV can achieve the maximum possible result. For instance, the engineers added two additional thrusters for ascending and descending. Based on the results of the last MATE ROV competition, Red Sea Robotics identified some shortcomings of the previous ROV, including a substantial lack of lift capability. Therefore, Red Sea Robotics now has four lift motors, one on each corner. Not only does Tyrone IV get a lift benefit, but now, much like a helicopter, aeroplane, or drone, Tyrone IV can have a roll and pitch axis with the simple addition of the new thrusters. This allows for more precise manoeuvrability, and the roll enables the Tyrone IV to not require a sway motor due to the swaying created by the thrusters, much like a

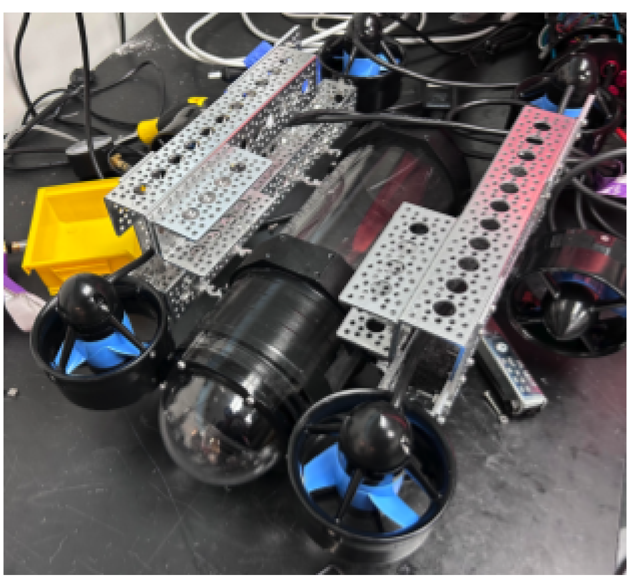


Figure 7: Improved Frame Structure for Gripper Arm

drone would. The team also maintained the more streamlined approach with the previous Tyrone III frame. As seen in **Figure 10**, 2023 year's Tyrone II's frame had a very boxy and inefficient design. Adapting this frame into a newer, more compact, and more streamlined design in 2024 allowed for a smaller cross-section and, thus, greater efficiency of our design, where success was seen through an over 50% increase in product demonstration score from 2023-2024. Therefore, we chose to retain our 2024 frame design. This small cross-section can be seen in **Figure 8**.

Further innovation with reduced cost can be noted regarding the motors. Due to the drone-like nature of the ROV, the ROV removes the need of additional thrusters significantly reducing build cost, as we can usually see ROVs, (especially bluerobotics ones) using upwards of 8 thrusters, with levels of maneuverability that our ROV achieves with only 6 In addition, our team was able to step away from off the shelf components such as the Blue Robotics framework, which could be and was replaced with a more cost-effective solution with our Actobotics frame. It's also important to note that the team used less material on this frame compared to last year, which is an excellent bonus for the team regarding responsible material usage and greater flexibility when adding new components; with new frame parts, we could later add.

Figure 8: Top View of Tyrone IV

Furthermore, the use of 'Actobotics' frame parts allows the team to mount motors, the capsule, and the grabber's arm reasonably quickly, with lots of opportunities to modify, should the need arise. Innovation is very active, and it is ever-changing with new requirements. Having a frame that can be adapted quickly is equally important to solving design problems as the solution, as without a means to a solution, it may never be adequately implemented.

Problem-Solving

Upon having exposure and experience from the 2024 World Championship, the Red Sea Robotics team evaluated and studied the Tyrone III (2024 version) and then improvised with brainstorming and implemented it into pool testing later on. The team understood that there was an excess use of aluminum taking up a larger cross-section than was necessary, and therefore, the team minimized the use of aluminum frame parts; however, they maintained the open and efficient thruster layout, as that showed itself as a strong point during testing and the 2024 championship. Therefore, this has led to the disassembly and subsequent reassembly of the aluminum frame and the implementation of a new design, as seen in **Figure 10**. This allowed for reduced mass and better stability and maneuverability in Tyrone IV.

Figure 10: Disassembling Tyrone III (Previous ROV)

Additionally, the team used resources conservatively. This allowed for the utilisation of the parts needed for the ROV. The reused, bought, and built components are further discussed in Build vs Buy & New vs Used

Vehicle Structure, Systems & Systems Approach

The Tyrone IV ROV is our most advanced and reliable ROV to date. It features a compact, custom, and versatile framing structure, six T-200 Blue Robotics thrusters for maximum power and lift, a Blue Robotics Newton Subsea Gripper Arm to achieve maximum tasks with reliability, and a Blue Robotics 6” series-sized watertight enclosure tube to hold all of our essential components. The Tyrone IV is an incredible achievement for the entire Red Sea Robotics Team.

Figure 11: Gripper Arm

The horizontal length of the ROV is 0.58 meters, the total width is 0.46 meters, and the total height is 0.18 meters. This includes the top of the watertight enclosure and the bottom floor of the gripper arm. The weight of the Tyrone IV is 8.14 kilograms. The weight and dimensions meet the mission requirements.

The Blue Robotics Newton subsea gripper arm was selected based on its capability and reliability while executing grabbing and manipulation functions. This gripper arm is firmly attached to the ROV's frame and can be operated using a controller from the control pilot station. The gripper's jaws open to 2.44″ or 0.062m, allowing the Tyrone IV to assist in performing all necessary tasks. For instance, it can grab the handle of a container lid, allowing the pilot to see the contents of the container. Once the pilot has identified the material, the pilot can navigate the lid back to the container, releasing the grabber arm, closing the container, and completing the Task 1.1. The gripper is rated at 300m, which is highly safe in shallow-depth environments. Although the gripper arm has an expensive price tag of $690 USD, the team decided to invest in it due to its reputation and ability to perform. It will be beneficial for meeting the mission requirements this year as the task mostly consists of grabbing, turning, and transporting the props.

The frame of Tyrone IV is built from a precision-cut aluminium system that's both lightweight and durable, making it ideal for underwater missions. Its modular design - with evenly spaced holes - gives the team a lot of flexibility when attaching components like the T200 thrusters, gripper arm, and watertight enclosures. The layout is also fully compatible with Blue Robotics hardware, which made integration much smoother during assembly. One of the biggest advantages of this system is how easy it is to adapt. During pool testing, for example, the team was able to quickly tweak the frame layout to solve issues or try new configurations. This adaptability helped streamline the prototyping process and made troubleshooting more efficient. To support the frame, the team also designed and incorporated custom 3D-printed parts and laser-cut acrylic panels, adding strength and precision where needed. While this setup worked well for this year's build, there were a few limitations. Some parts were tricky to mount due to the fixed hole pattern, and not every custom idea could be easily implemented. In the future, the team is looking into more customizable framing options to push the boundaries of design even further.

To enable full control of Tyrone IV during underwater missions, the team selected six Blue Robotics T-200 thrusters for their reliable performance, strong thrust-to-weight ratio, and precise manoeuvrability. These motors were configured strategically to support the ROV's movement across multiple degrees of freedom, as illustrated in Figure 11.1. The thruster configuration includes two horizontally aligned thrusters along the x-axis (forward and backwards), enabling surge motion and contributing to yaw control through differential thrust. This allows Tyrone IV to move efficiently in straight lines and rotate smoothly when needed. To improve heave (vertical motion), four upward-facing thrusters were installed. This was a key improvement from last year's design, where limited lift capability often caused instability. For example, when trying to lift an object from the seafloor, the previous ROV would tilt or even flip due to insufficient upward thrust. In tasks requiring delicate manoeuvring, such as hooking a carabiner, the lack of vertical force made it impossible to complete the action. The new configuration addresses these issues directly, providing reliable lift and precise vertical control. This year, the team intentionally used sway (y-axis) thrusters, focusing instead on optimising the essential degrees of movement: surge, heave, and yaw, which are

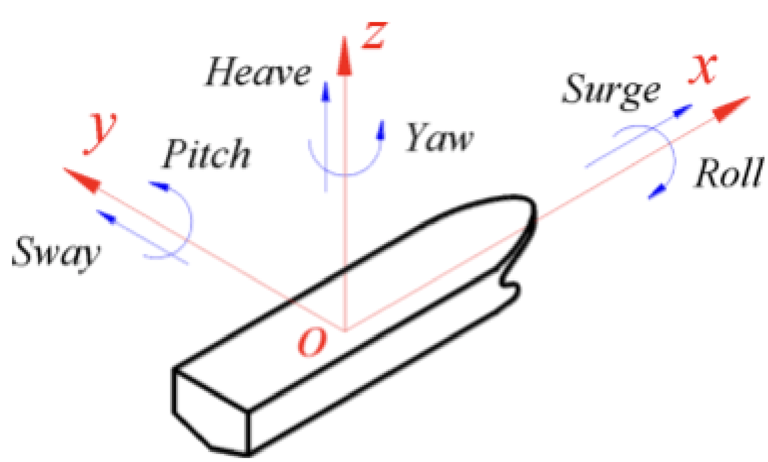


Figure 11.1: 6 Degrees of Freedom Diagram
Credit: Roy de Winter

most critical to the mission objectives. All T-200 thrusters are wired into the central Blue Robotics watertight electronics capsule. A trade-off of using these high-performance motors is their high current draw, which requires a thicker tether wire gauge. While this adds some extra weight to the tether, it ensures consistent and powerful motor performance.

Electrical System

The technical team made the decision not to use a motor controller, such as the Pixahawk seen in the BlueROV2, and to instead rely on a computer module, the Raspberry Pi 3 model B, on the ROV to receive controls and write to each of the 6 Blue Robotics T200 Thrusters, as well as to write to the Blue Robotics Newton Subsea Gripper. This decision was made so that sensors, such as the USB camera and the Blue Robotics “Celsius Fast-Response” thermometer, can be read and relayed to the surface in the same unit that handles controls and the thrusters. The signals are transmitted via an Ethernet cable pair, linked by two FathomX Tether Interfaces on either end. The FathomX allows the signal to be used as an Ethernet connection on both the Raspberry Pi and the surface computer, allowing for convenient SSH and remote GPIO control access.

Within the control system, the input from the Logitech Wired Controller is read and translated to thruster values on the surface with a Python program. The final thruster values are sent to the Raspberry Pi to directly write to the thrusters with minimal work on the Raspberry Pi’s end. The grabber arm and camera servo values are also calculated on the surface and sent to the ROV. The thruster values and the controller mappings are determined by several movement modes, such as “BALANCED” and “LIFT”. For example, in “LIFT”, additional thrust is applied to the forward upwards thrusters and thrust is reduced for the forward thrusters to redirect power, allowing the ROV to lift heavier items. The sensors on the ROV, such as the thermometer, are interfaced with “drivers” that connect to each sensor and process the data into a human-readable format. Usually, this involves code for an I2C interface as for the thermometer, to facilitate two-way communication between the surface controls and the thermometer. The Raspberry Pi uses Gstreamer to run a 720p 24fps feed of the USB camera and streams it via Ethernet to the surface, where Gstreamer then renders it. This is the heaviest operation performed on the Raspberry Pi, and begins automatically as the ROV is powered on.

The code on the surface is designed with reliability in mind, meticulously tested so that errors will not occur, and in the case that they do, it is quick to restart the system in under 12 seconds. Each component of the ROV is represented by a “connection lifecycle”, where, when the system starts, several attempts are made to open a connection with each component. In the case that a component could not be connected to (for example, due to a wiring issue caused by a collision), then the system safely logs a warning message for the pilot without disrupting the overall system. When the system is stopped by the pilot, all active connections are individually stopped safely. With this design philosophy, the ROV control system can run independently of any components functioning, to such an extent that it will still attempt to run the ROV even if the thrusters, gripper arm and the camera fail to connect.

12V power is supplied on a ten-gauge wire with a 20A fuse. Power is first run through the surface control box, powering the surface FathomX board, then is sent along 15m of tether to the ROV. The tether consists of four wires in a mesh sheath, two of which are ten-gauge power, and the other two are 26-gauge Ethernet. The Ethernet wire is part of a 6-wire Ethernet cable, which was used in case of changes to the design. However, ultimately, only two wires were used. According to Blue Robotics specifications, the FathomX supports HD video and signals on up to 300m Ethernet tether. Therefore, 15m of tether is sufficient for our context. Power is distributed with two 8-circuit barrier blocks from DigiKey for 12V and ground. A Ubec 5V3A Boost Converter manages power to the Raspberry Pi, and each FathomX board is directly powered as it accepts 12V. The tether is secured with strain reliefs on both ends to prevent direct force on connections.

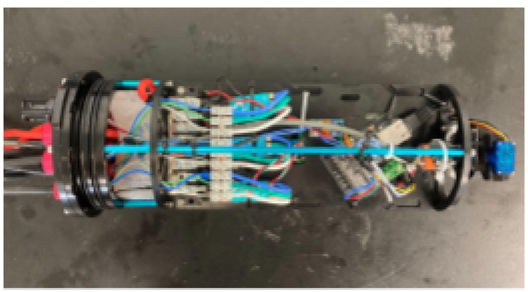


Figure 12: Electronic Capsule Components

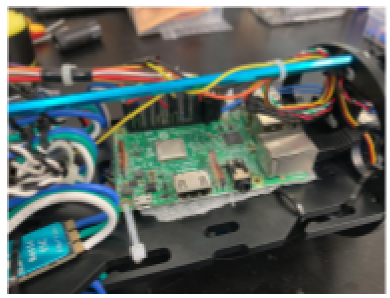


Fig 12.1: electronics within the main compartment

Connections to the electronics capsule are ensured to be watertight using the Blue Robotics WetLink Penetrators, which are compatible with the endcap. The penetrators were sealed by engineers with an O-ring lubricated with silicon grease and potted using marine epoxy. Inside the ROV, a Leak Sensor module is utilised by having two small humidity-sensitive sponges in critical points that close the circuit, indicating a leak and causing a persistent warning to appear on the surface computer. A silica gel packet will be placed in the connector's space, where a leak will likely occur.

The Tether is approximately 15 meters long and weighs 2.2 kg. This was decided based on the distance the tasks were around the swimming pool. The tether contains four wires: A 10-gauge power, a 10-gauge ground, and an Ethernet wire pair for communications. The electrical decisions behind the tether are described in the Electrical Section. The tether would be an efficient length for Tyrone IV, ensuring that Tyrone IV did not have too much or too little, as too much length could cause signal noise, and too little would limit Tyrone IV's ability to complete tasks.

The team added a series of tether flotations consisting of pool noodles cut into small sections and placed in intervals across the tether to float the tether and not create drag. The team also did not include a roll or spool wheel for the tether, as the tether has to completely mitigate the risk of kinks, as well as the risk of tether output. At some points, the tether operator needs to give out large lengths of tether into the water to meet the ROV's needs.

Tether management is crucial to the success of the team. To manage the tether during the product demonstration, the tether operator concentrates on providing an appropriate tether length to allow unimpeded movement of the ROV. They aim to provide the right amount of lead to prevent the possibility of tugging the ROV, with a short length of tether provided, which could lead to point deductions, and the possibility of too much length given, which could add extra weight to the ROV, affecting its buoyancy. In the case of an exigent circumstance with the tether, a procedure is followed. For example, if little to no tether length remains, the operator notifies the pilot early on. This mitigates the risk of the ROV overturning due to the sudden tension from the tether running out of length. Additionally, another instance is if the tether snags around a prop. The tetherman and pilot divert their attention to this issue and converse to untangle it as fast and efficiently as possible. Altogether, a tether operator is utilised that constantly feeds or removes the tether from the water to keep the ROV controlled and the tether management system effective and efficient.

Propulsion

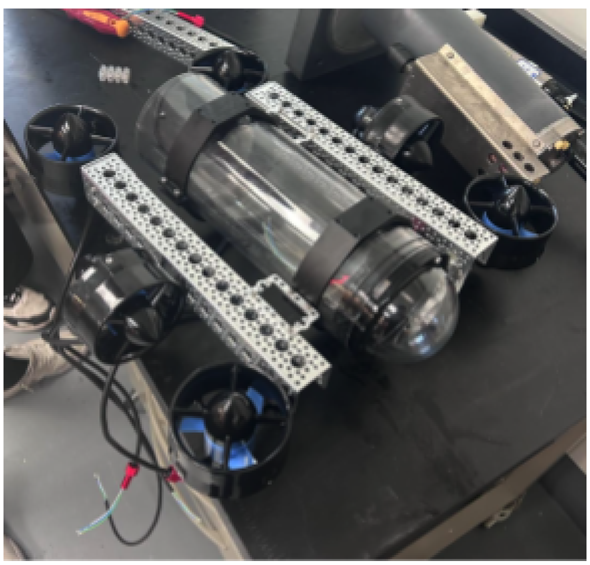


Figure 13: Thrusters

The team chose Blue Robotics T200 Thrusters for the Tyrone IV because they worked well in the previous ROV. Using the same type of thruster will make it easier to fit them into the new ROV design since the team is already familiar with them. The team added six thrusters to improve the Tyrone IV's stability and ability to move around. We put four thrusters pointing up and two pointing forward. This setup gives the ROV balanced power and good control over its movement in all directions. The T200 Thrusters cost $200 each. These thrusters are known to be reliable and powerful, which is important for the difficult tasks the Tyrone IV will have to do. The team has used these thrusters before and has been happy with how they perform. The T200 Thrusters' high power compared to their weight makes them good for tasks that need fast acceleration, precise positioning, and the ability to work against strong currents. This power and control are crucial for things like navigating through tight spaces, holding still during delicate work, and quickly responding to changes in the water. The thrusters are also built to be tough and waterproof, so they can handle the pressure and hazards of the underwater environment. This reliability reduces the chances of problems during important moments, allowing Tyrone IV to work confidently throughout the competition.

The ROV gains superior stability and buoyancy control by having four thrusters oriented upwards. In other words, the upward thrusters can lift heavy objects underwater. These upward-facing thrusters counteract the weight of the Tyrone IV, which allows the ROV to maintain a stable position underwater. Additionally, this configuration enables the ROV to execute vertical movements, such as ascending and descending, with ease and stability. Meanwhile, the two thrusters facing forward serve to enhance the ROV's forward propulsion and manoeuvrability. Placing thrusters in this orientation allows the ROV to move efficiently through the water, overcoming resistance and achieving higher speeds. Moreover, having forward-facing thrusters enables the ROV to execute complex manoeuvres. The placement of six thrusters is seen in **Figure 13.** (Shrouds not present during construction in **Figure 13**)

Buoyancy and Ballast

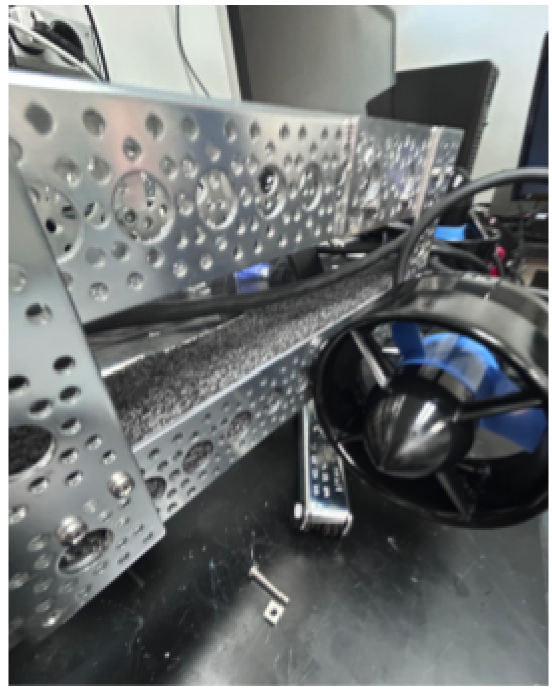


Figure 14: Foam Inside the Frame

The frame utilises a system of integrated flotation to maintain buoyancy in the ROV. With the Tyrone IV, the team aims to establish complete neutral buoyancy. Since the Tyrone IV has a heavy aluminium frame, six motors, and a grabber, there is a substantial level of negative buoyancy. To counteract this, Tyrone IV underwent an operation where the team installed foam in the empty sections of our U-shaped framework, as seen in **Figure 14**. It is also important to note the effect of the positioning of the grabber arm and the placement of the electronics capsule. The electronics capsule doubles as a source of ample buoyancy, as it has a large air volume, increasing its positive buoyancy coefficient. There is, however, an issue of ballast on the ROV due to the placement of our grabber arm. The grabber arm, which has a noticeable mass, is placed on the front of the ROV (see **Figure 11**). Thus, this placement causes a forward-pitching motion of the ROV, which should be avoided. To counteract this, the team added more flotation in our integrated systems closer to the front of the ROV. The Tyrone IV is expected to be capable of lifting heavy objects. Therefore, the team has decided to keep two lift motors close to the front of the ROV to counteract this front tilting motion that the ROV would experience should it lift or manipulate an object during product demonstration. (Side note: the team tries to establish the most symmetrical ROV they can to maintain a flat and level ROV attitude when not manoeuvring.) Furthermore, the ROV can encounter situations where heavy objects need to be lifted and sung from side to side or placed in a designated area. For example, in Task 2.2, a weighted hydrophone must be removed from its platform and placed in a designated yellow square. To address this ballast issue with movement, the ROV can use roll to its advantage. Like a drone, the roll motion combined with heave inputs on the upwards-facing thrusters can create a rather powerful sway motion as the ROV is rolled onto its side, repurposing all 4 heave thrusters into sway thrusters.

Payload and Tools

The Tyrone IV has one 720p USB camera, as it effectively gives the pilots a clear view underwater while being energy efficient. The camera is placed within the watertight enclosure and attached to a servo, allowing for vertical rotation, primarily to keep the gripper in view when convenient, as seen in **Figure 15**. This allows tasks to be completed more effectively as the pilot with help of the vertically rotating camera, can view the tasks from multiple angles, allowing for increased vision. This is especially important for tasks such as seen in figure 16. The camera feed is streamed with GStreamer on an Ethernet tether to be rendered on the surface computer, as seen in **Figure 16**.

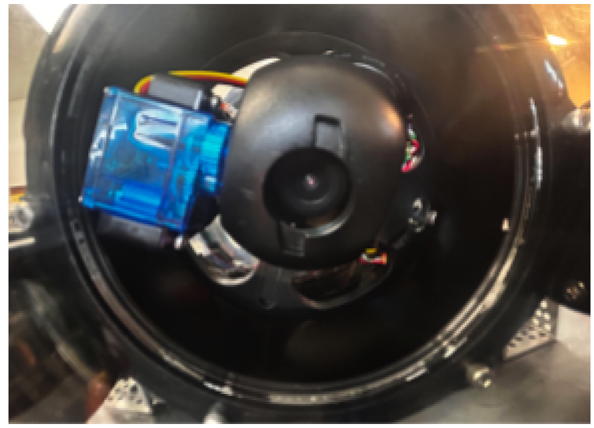


Figure 15: Tyrone IV Camera

Figure 16: Monitor Footage from Tyrone IV Camera

Other essential tools utilised in Tyrone IV consist of the Newton Subsea Gripper, six T200 Thrusters, and the Watertight Enclosure. The Gripper handles items and recovers them in several underwater mission tasks. For instance, task 2.1 requires the ROV to grab a power connector and install it to the connection port. To meet this requirement, the pilot can see the gripper arm below and effectively grab and transfer the connector to the port. The BlueRobotics Thrusters provide efficient propulsion and accurate movement, allowing for navigation underwater and completing the task and mission; the trade-off is discussed in Vehicle Structure, Systems & Systems Approach. The watertight enclosure protects critical electrical components, increasing protection and longevity in underwater circumstances. Together, these payload tools enable the Tyrone IV to effectively conduct a wide range of activities, helping to the effectiveness of underwater operations in various situations and tasks required to complete. Additionally, the sensors in Tyrone IV are discussed in Electrical Systems.

Build vs. Buy & New vs. Used

Red Sea Robotics strongly believes in reusing materials to be sustainable and efficient in building the Tyrone IV. The team has used chiefly parts from the previous ROV, Tyrone III, which was successful in the international competition of 2024. However, Red Sea Robotics also bought new parts that were necessary to improve the ROV. It is to be noted that Red Sea Robotics was short on budget (further discussed in Accounting), so the team had to be wise with spending and reusing specific components. Therefore, the team reused aluminum frames to minimise the cost of buying them and meet the weight limit. We decided to continue using these aluminum frames as they met our requirements well and allowed us to compete to a satisfactory level last year.

Additionally, the team reused the watertight enclosure, four thrusters, and an electronics capsule. However, the team has bought the Newton Subsea gripper Arm, Raspberry Pi Processor, Tether, and two new Blue Robotics Thrusters for improved movement options. This upgrade will meet the mission requirements, as having more thrusters means that the Tyrone IV can efficiently do vertical profiling and vector thrust. This will ensure that the task is met, for example, the thrusters will be able to help lift heavy object,s such as grabbing the carabiner and dragging it to a new location. Nonetheless, below is the list table of reused, built, and purchased.

Built, purchased, or reused, Red Sea Robotics believes in ensuring parts are fitted, considering all aspects of development from costs, performance, and sustainability in terms of environmental impact.

Reused	Built	Purchased
- Aluminum Frame - Watertight Enclosure	- Safety Guard - Tether - Surface Control Box	- Newton Subsea Gripper - Rotation Servo - Arduino Nano - 25m Sheath - 25m cable - Camera - FathomX Interface - 6 T200 Thrusters

Safety

Our Philosophy

Red Sea Robotics takes pride in putting everyone's safety first. We guarantee that all our team members are safe and comfortable, allowing them to do the most outstanding quality full job possible. We want to provide a secure atmosphere in which our members may master their skills and demonstrate their abilities on a worldwide scale. Our members strictly adhere to the Job Safety Analysis to guarantee safe launch, recovery, and waterside operations below and above water.

Safety Content & Procedures

Red Sea Robotics' priority is the safety and well-being of its members. To guarantee this, all members must wear particular personal protection equipment, such as safety glasses, shoes/boots, lab coats, and gloves, at all times. A fire extinguisher, eyewash station, and first aid kit should all be readily available in the lab. All danger and warning zones are correctly marked with neon and visually recognisable signs. All team members are required to strictly follow lab rules and procedures with no margin for mistakes.

The ROV's body form and structure are designed to be as robust and rigid as possible, with safety and efficiency as the top priorities. Wires, fasteners, connections, and sealants are carefully selected to avoid underwater issues. The thrusters have thruster guards to prevent blade injuries and things from being lodged. These guards fulfil IP-20 specifications, guaranteeing the mesh size is below 12.5mm. All electronic components are safeguarded by enclosing them in a clear acrylic tube sealed with end caps with double O-rings on each side, and the end caps are clamped down with 6 M3 bolts on either end. While above water, the ROV is intended to be carried by its frame to eliminate the need for handles and facilitate more straightforward transportation. All fastenings and safety attachments were also smoothed to ensure that the fixtures were not a safety hazard. There has been a leak sensor installed in the ROV, which could detect leaks and warn the ROV pilot to bring the ROV back to the surface and power it off in the case of a leak. Additionally, we have installed 3D-printed safety guards onto the aluminium frame to enhance the safety of the ROV. An example of our safety guard is seen in **Figure 17.** The safety checklist and job analysis are in Appendix B and Appendix C, respectively.

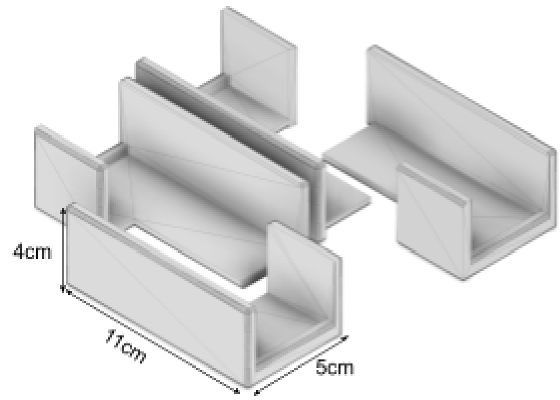


Figure 17: Safety Guard for Edge Steel Frames

Critical Analysis

Testing and Troubleshooting

Tyrone IV was examined during our monthly pool tests to troubleshoot and monitor its performance. The methodology of testing the ROV involved assessing three key aspects: motor speed, motor lift, and lift capacity. The six Blue Robotics T-200 thrusters were individually tested to evaluate motor speed. The ROV was placed in a controlled environment, and the speed of each thruster was measured using appropriate instrumentation. This

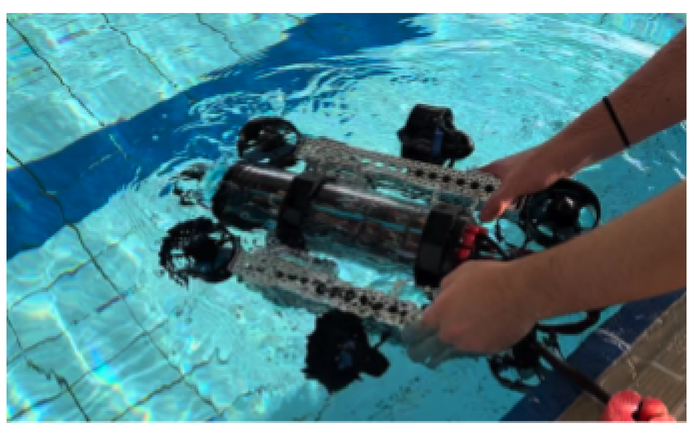


Figure 18: Testing Tyrone IV in the pool

allowed the engineers to ensure that all thrusters were functioning optimally, providing consistent and reliable propulsion for the ROV.

The motor lift capability was tested by gradually increasing the load applied to the ROV's gripper arm. Starting with minimal weight, different objects of increasing mass were securely picked up using the gripper arm. The ROV's ability to lift and manoeuvre the objects was observed and recorded. This test ensured that the motor lift mechanism could effectively handle the expected loads during operational tasks.

The lift capacity of the ROV was determined by progressively increasing the weight of objects being lifted until the ROV reached its maximum lifting capacity. This test allowed the team to establish the maximum weight the ROV could safely handle without compromising its stability or performance. It provided valuable information for operational planning and ensured that the ROV's capabilities were aligned with the intended tasks.

Data such as motor speed, lift capacity, and any observed anomalies or issues were documented and analysed throughout the testing process. This allowed the team to identify any performance limitations or areas for improvement and make necessary adjustments to optimise the ROV's functionality and reliability.

By conducting comprehensive testing of motor speed, motor lift, and lift capacity, we ensured that the Tyrone IV ROV's propulsion and lifting systems were functioning as expected and capable of meeting the operational requirements of our underwater tasks.

Testing Data:

Motor Thrust Setting (%)	Forward/Backward Motor Speed (ms^{-1})					Average
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	
40	0.505	0.487	0.476	0.457	0.500	0.485
50	0.575	0.561	0.575	0.544	0.577	0.566
60	0.671	0.657	0.628	0.674	0.667	0.659

Motor Thrust Setting (%)	Up/Down Motor Speed (ms^{-1})					Average
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	
40	0.757	0.745	0.758	0.765	0.777	0.760

50	0.804	0.813	0.833	0.823	0.842	0.823
60	0.878	0.902	0.921	0.895	0.945	0.908

Motor Thrust	
Direction	Thrust (kg ± 0.0005)
Forward	4.8200
Backward	3.7800
Up	9.6500
Down	7.5900
Left	N/A (lack of sway motor)
Right	N/A (lack of sway motor)

During testing, the team experimented with a custom buoyancy system by attaching empty PVC pipes along the top of Tyrone IV in an attempt to achieve neutral buoyancy. This approach was chosen to eliminate the inconsistencies of traditional foam, which can absorb water over time and lead to unpredictable buoyancy levels.

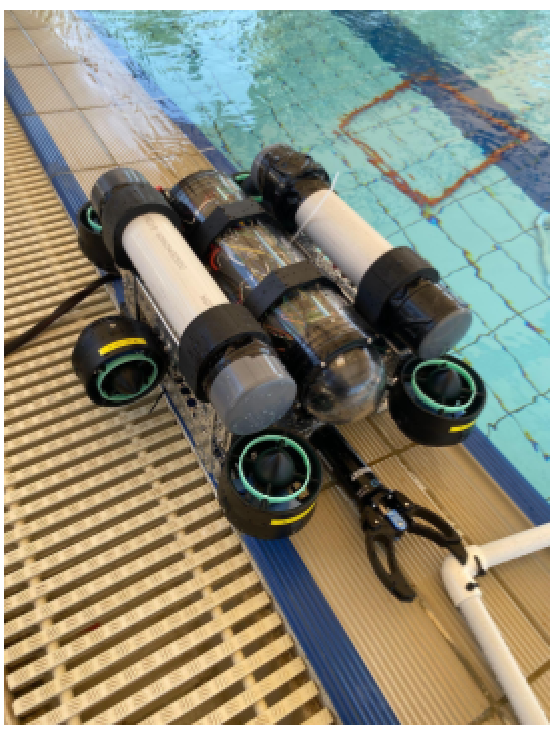


Figure 18.1: Tyrone Buoyancy System Test

However, testing revealed that the PVC setup made the ROV excessively top-heavy. As a result, Tyrone IV became too buoyant at the top, which significantly limited its ability to **roll** and **pitch** effectively. These restricted movements posed challenges during tasks that required fine angular adjustments underwater.

This issue was noted as a key finding in the **Troubleshooting** phase and has informed future design iterations to ensure a more balanced and controllable buoyancy system.

Accounting

Budget

Red Sea Robotics had previously gotten funds to make a purchase of components that would need to last for the team for at least four competition seasons. Hence, thereafter, the team had to be both creative and cost-effective with the budget. The above-mentioned funding for Red Sea Robotics prioritised purchasing necessary components such as the thrusters, a tether, and a watertight capsule. These were prioritised because of their individual importance and immense contribution to the performance of the ROV, as mentioned in previous sections of the documentation. The team planned out the essential parts required in shared documents, where the parts would be ordered and shipped. Each team member wrote the parts needed for the shared document. Then, the prioritised parts were ordered. The actual money spent on components is roughly 2500 USD, with the rest of the components either being donated or reused. However, it should be noted that, in some cases, the shipping cost is not included, so the value may exceed the expected total cost. Furthermore, there are different types of funds. As seen in the 'Fund Type' column on the cost accounting table, the 'Sponsored' Fund type is the money being funded to Red Sea Robotics, and 'reused' is the material that has been used before and is being used again. The 'Donated' fund type is when another organisation provides Red Sea Robotics with the product, whereas 'Purchased' is when the Red Sea Robotics team spends its own costs (coming from members of the team).

Cost Accounting

Category	Expenses + Description	Quantity	Fund Type	Total Cost (USD$)
Hardware	Bluerobotics Newton Subsea Gripper	1	Sponsored	690.00
Hardware	Precision-cut aluminium assembly solution	1	Reused	231.00
Hardware	Rotation Servo	3	Sponsored	25.00
Hardware	RC controller	1	Sponsored	42.00
Electronics	Arduino Nano	1	Sponsored	65.00
Other	Thermometer	1	Sponsored	70.00
General	~25m Sheath	1	Sponsored	64.00
General	~25m Cable (10 Gauge)	1	Sponsored	85.00

Electronics	Camera	1	Sponsored	99.00
Electronics	FathomX Interface	1	Sponsored	120.00
Other	Syringe 150ml	2	Sponsored	15.00
Hardware	Bluerobotics T200 Thrusters + ESCs	6	Sponsored	1,428.00
Hardware	Bluerobotics 4” Acrylic Tube + Covers and Plugs	1	Sponsored	213.00
Electronics	Raspberry Pi 4	1	Sponsored	100.00
Electronics	Breadboard	2	Donated	15.00
Hardware	Watertight Enclosure (0.1 m)	1	Sponsored	230.00
Hardware	End Cap (0.1 m) 18 x M10 Hole	1	Sponsored	55.00
Hardware	O-Ring Sealing Flange (0.1 m)	2	Sponsored	90.00
Hardware	Eng Cap (0.1) Dome	1	Sponsored	40.00
Hardware	Vent/Pressure Relief Valve	1	Sponsored	10.00
Hardware	Potted Cable Penetrator	9	Sponsored	45.00
Hardware	Penetrator Blank	6	Sponsored	30.00
General	25A Fuse Package	1	Purchased	6.67
Electronics	Fuse Holders	6	Purchased	16.38
Electronics	Arduino Wireless Bluetooth Controller	1	Purchased	9.61
Hardware	Strain Relief	1	Sponsored	24.98
Hardware	Hard Shell Control Box	1	Sponsored	50.00
Merchandise	T-Shirts and Hats for Regional Competition	9	Purchased	130
Merchandise	Hoodies, Hats, Sunglasses, Tote bags	13	Purchased	106.64
Merchandise	Team Polo Shirts, Hoodies, Hats, Banners, etc.	24	Purchased	250
			Total	4,356.28

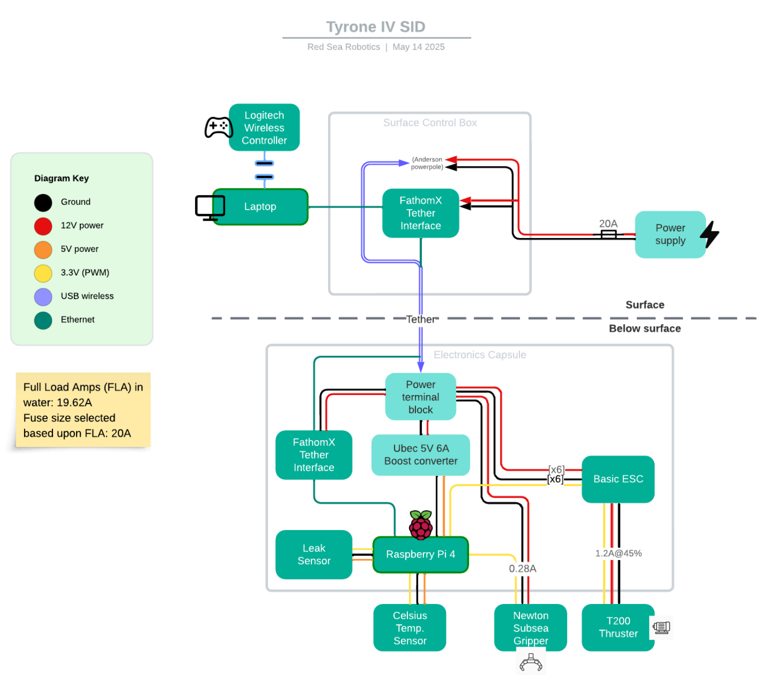
Acknowledgments

Red Sea Robotics would like to express enormous gratitude and appreciation for the opportunity to participate in the 2025 MATE ROV program for the third time. We are immensely thankful to the MATE Centre, Marine Technology Society, and our various internal sponsors for their significant contribution to our journey. We would like to thank our regional sponsors, CEMSE, KAUST Beacon Development and OceanQuest. And a special thank you to the KAUST Coral Restoration Initiative for immense and crucial funding, enabling us to travel to the United States of America for the previous world competition. The KAUST Enrichment for Youth (KEY) has been instrumental in organising the regional competition and logistics. We would like to extend our hands to KAUST Coastal, Marine Resources Core Lab and the Prototyping and Product Development Core Lab for their funding, assistance, and resources, and, lastly, the KAUST School for their help and the opportunity to participate in the MATE ROV program and financial support in sponsoring the team with critical ROV parts. Additionally, we would like to thank our supervisor for their generous assistance with equipment and guidance. Furthermore, we take great pride in representing Saudi Arabia twice already in this prestigious competition, showcasing our commitment to marine technology and education that drives a sustainable future. We are deeply grateful for the invaluable support we have received. Lastly, the team would like to thank and acknowledge the support from our parents, who have been pivotal in encouraging us to push through challenges and to allow us to be part of this meaningful journey.

Appendix

Appendix A:

Tyrone IV ROV's SID



Appendix B: Job Safety Checklist

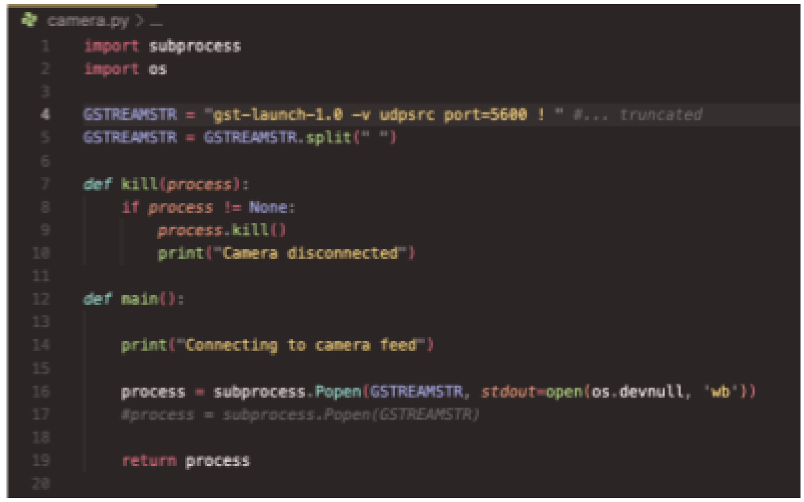
Precaution	YES	NO
Personal Protective Equipment (PPE) - Ensure all team members are wearing PPE such as safety glasses, gloves, and closed-toe shoes to protect against physical and chemical hazards. - Ensure team members are wearing appropriate clothing that does not pose a risk of entanglement or snagging in machinery.		
Emergency Procedures - Have a clearly defined emergency plan in case of an accident, including emergency contacts, evacuation routes, and first-aid procedures. - Conduct regular safety drills to ensure all team members know what to do in case of an emergency.		
Equipment Safety - Inspect and test equipment before use to ensure it is in good condition and functioning properly. - Ensure all equipment is properly maintained, cleaned, and stored after use. - Use equipment only for its intended purpose and follow manufacturer instructions.		
Electrical Safety - Ensure all electrical equipment is properly grounded and meets safety standards. - Use circuit breakers, fuses, and other protective devices to prevent electrical hazards.		
Hazardous Materials - Identify and properly handle any hazardous materials used in the robotics laboratory, such as chemicals, batteries, and lubricants. - Ensure all hazardous materials are properly labeled, stored, and disposed of.		
Fire Safety - Have appropriate fire extinguishers readily available and ensure team members are trained on their proper use. - Regularly inspect and maintain fire suppression systems and smoke detectors.		

Appendix C: Job Safety Analysis

Job	Hazards	Controls
1. Mechanical Engineer	Heavy Lifting, Chemical Burns, Blade Cuts, Moving Parts and Pinch Points	Heavy Lifting course, Blade Safety Rules, Pinch Points Safety Lesson, Lab Safety Course and Rules
2. Electrical Engineer	Electrocution, Soldering Burns, Heat Gun Burns, Shorting Equipment, Exposed Wires	Soldering and Electrocution Safety Course, Heat Glove enforced during use of Heat Gun and Soldering Iron, Lab Safety Course and Rules
3. Pilot	Electrocution, Drowning, Robot Catching on Fire, Blade Cuts, Controls Exploding	Pool Safety and Swimming Aptitude Test, Life Guards on Duty at all times, Fire Safety Course, First Aid Basic Course, Blade Safety Rules, Lab Safety Course and Rules
4. Tetherman	Electrocution, Drowning, Robot Catching on Fire, Blade Cuts, Controls Exploding	Pool Safety and Swimming Aptitude Test, Life Guards on Duty at all times, Fire Safety Course, First Aid Basic Course, Blade Safety Rules, Lab Safety Course and Rules
5. Co-Pilot	Electrocution, Drowning, Robot Catching on Fire, Blade Cuts, Controls Exploding	Pool Safety and Swimming Aptitude Test, Life Guards on Duty at all times, Fire Safety Course, First Aid Basic Course, Blade Safety Rules, Lab Safety Course and Rules
6. Frame Builder	Cutting Tools, PVC Shattering, Hot Glue Burn, Chemical Burn and Paint Poisoning	Blade Safety rules, Gloves being worn during construction processes, Chemical Safety rules and Lab Safety Course and Rules
7. Chief Financial Officer	Carpal Tunnel, Workplace Stress, Office Hazards	Arm Exercises to reduce strain of wrist, Daily Meditation and Mindfulness Sessions, Lab Safety Course, Office Safety Course
8. Chief Executive Officer	Carpal Tunnel, Workplace Stress, Office Hazards	Arm Exercises to reduce strain of wrist, Daily Meditation and Mindfulness Sessions, Lab Safety Course, Office Safety Course
9. Non-ROV Tetherman	Electrocution, Drowning, Robot Catching on Fire, Blade Cuts, Controls Exploding	Pool Safety and Swimming Aptitude Test, Life Guards on Duty at all times, Fire Safety Course, First Aid Basic Course, Blade Safety Rules, Lab Safety Course and Rules
10. Non-ROV Dataman	Electrocution, Drowning, Robot Catching on Fire, Blade Cuts, Controls Exploding	Pool Safety and Swimming Aptitude Test, Life Guards on Duty at all times, Fire Safety Course, First Aid Basic Course, Blade Safety Rules, Lab Safety Course and Rules

Required Training:	Required Personal Protective Equipment (PPE)
-Lab Safety Course -Pool Safety and Swimming Aptitude Test -First Aid Basic Course -Pinch Points Lesson and Blade Safety Rules -Safe Heavy Lifting Course -Mindfulness and Stress reduction Course	- Lab Coat - (PPE Certified) Lab Goggles - (PPE Certified) Heat Resistant Gloves - (PPE Certified) Boots with Metal Frame

Appendix D: Tyrone IV Software Code



References

"Archives." MATE ROV Competition, https://materovcompetition.org/archives.

"Blue Robotics T200 Thruster." Carcinus Ltd, https://www.carcinus.co.uk/product/blue-robotics-t200-thruster/.

"Newton Subsea Gripper." Marine Thinking, http://store.marinethinking.com/products/newton-subsea-gripper.

de Winter, Roy. "Roll, pitch, yaw, heave, sway, surge of a ship." *Designing Ships Using Constrained Multi-Objective Efficient Global Optimization*, May 2018, https://www.researchgate.net/figure/Roll-pitch-yaw-heave-sway-surge-of-a-ship_fig5_327838620