TECHNICAL REPORT

TITANS ROV '25

ALEXANDRIA UNIVERSITIES | ALEXANDRIA, EGYPT

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Acknowledgements

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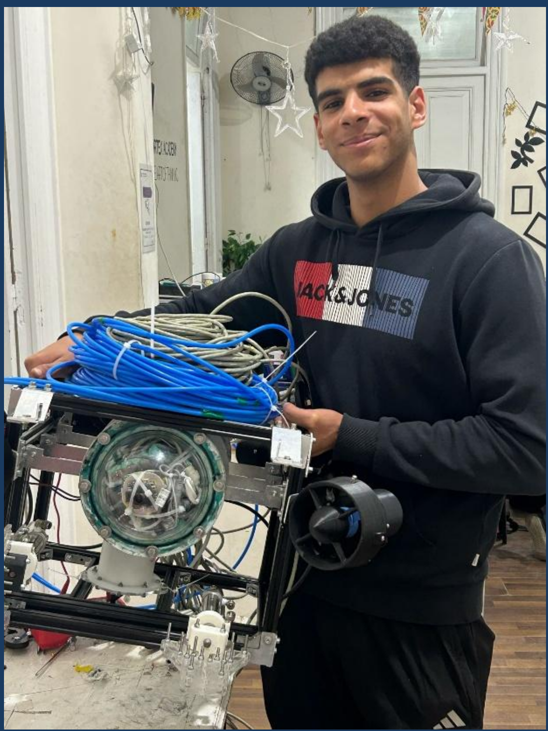
Abstract

This report presents *Cronus*, the first Remotely Operated Vehicle (ROV) developed by the Titans team for the 2025 MATE ROV Competition – Pioneers class. Designed to perform complex underwater missions such as shipwreck measurement, sample collection, and debris recovery, Cronus emphasizes adaptability, reliability, and cost-efficiency. Throughout the development process, the team prioritized modular design, safety, and reusability. Key findings include the successful implementation of alternative propulsion methods, an accurate low-cost measurement system, and an innovative sampling tool that proved more effective than traditional solutions. The project highlights the team's ability to transform challenges into opportunities for learning and innovation, resulting in a robust and mission-ready ROV.



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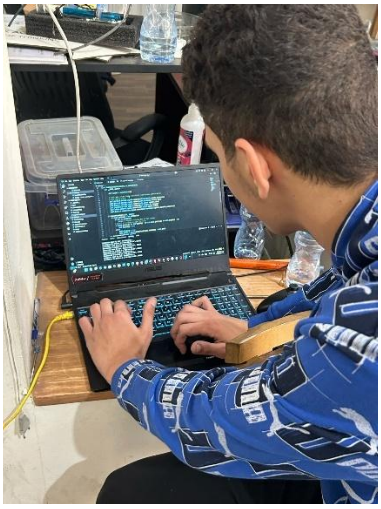

1 Teamwork

1.1 Company organization:

Titans, mentored by Vortex Academy, is a team of students working together to build and operate an ROV while achieving team goals and encouraging the gain of new experiences. The team is organized in a way that helps everyone know their job and work together smoothly. The CEO manages the whole team and keeps everything on track. The CTO supports all tracks with technical guidance.

The team is divided into three main technical departments (as shown in figure 1):

- Software: Split into three smaller teams, which are control, computer vision, and GUI
- Electrical: Creates circuits and designs the PCB
- Mechanical: Designs and builds the frame and movement systems.

Each department is led by a Functional Manager who assigns tasks and follows up on progress. We also have Project Managers who focus on special parts of the project, like the float system and tools. On the non-technical side, a team handles the technical report, media, poster, and presentation to make sure the team looks professional. Everyone has a role, and all roles are important for the success of the team.

1.2 Project schedule:

As shown in the plan(figure 2), the project was divided into two phases: training and ROV development.

The training phase itself had two stages: basic and advanced.

In the basic training phase, all team members learned the basics of mechanical, electrical, and software systems used in building an ROV. During this time, the mechanical team learned about tools and materials, the software team practiced coding using Arduino and Python, and the electrical team studied circuit design and component safety.

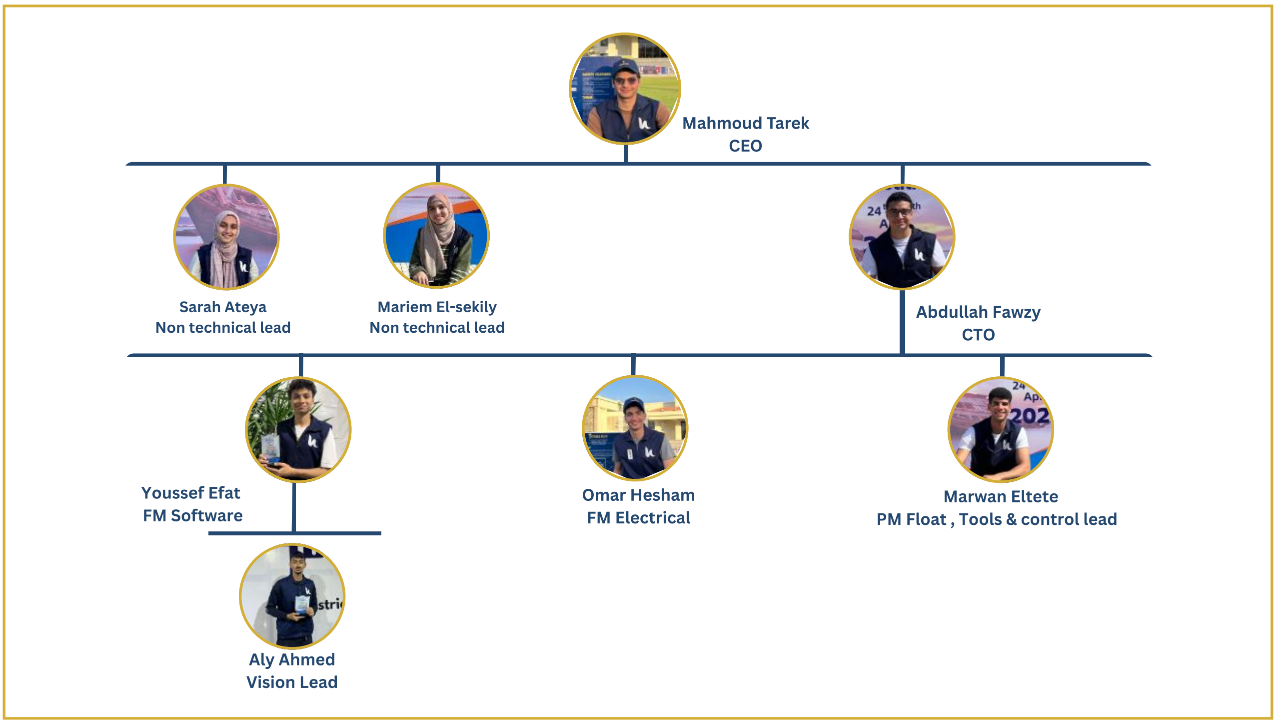

Figure 1 company hierarchy , designed by Salma Hussain using Canva

Then came the advanced training phase, where team members were divided into their specific departments. Each team focused on topics that matched their role. The mechanical team used SolidWorks to design a prototype frame for the ROV. The software team worked with programming languages like Python and focused on tasks such as writing control code and image processing. The electrical team practiced designing circuits and even tried making simple printed circuit boards (PCBs). At the end of the training, we built a small prototype ROV called “Nile fish”, (as shown in figure 2) which helped us test what we learned before building the final robot; this prototype was a big step in the preparation of the final ROV.

Figure 2 Nile fish ROV

After training, the team entered the development phase, where the real ROV started coming to life. Each department began working on its main responsibilities. The mechanical team built the actual frame and installed thrusters and tools. The electrical team connected all the wiring, sensors, and power systems, and tested the PCB that would be used in the final robot. Meanwhile, the software team integrated their code to control movement, process video feeds, and run the entire system smoothly.

Throughout this phase, the team followed a timeline based on a Gantt chart to keep track of tasks and deadlines, in addition to weekly updates that helped everyone stay in sync. Members shared progress and solved problems together, which made sure the robot was ready on time. The non-technical team worked in parallel, preparing all the required documents, the presentation, and other materials for the competition. This organized schedule allowed the team to stay focused and complete the project efficiently.

After the regional competition, the team shifted its focus toward further development and improvements. The team began developing the float as required for the international phase. At the same time, the team worked on fixing any technical issues that appeared during the regional competition performance to ensure better results in the upcoming stage. Meanwhile, the non-technical team concentrated on improving the TDR and all other documents to make them exceptional and more aligned with the international standards.

ID	Task Mode	Task Name	Duration	Start
1		The whole project	112 days	Sun 1/19/25
2	✓	Training phase	27 days	Sun 1/19/25
3	✓	Planning phase	7 days	Sun 2/23/25
4	✓	design preperation	6 days	Mon 3/3/25
5	✓	manifacturing	12 days	Sun 3/9/25
6	✓	Documentation and presentation training	24 days	Sun 3/16/25
7	✓	Building the ROV	7 days	Sun 3/23/25
8	✓	Testing the ROV	12 days	Sun 3/30/25
9	✓	Regional ready ROV	0 days	Sat 4/12/25
10	✓	Training on the ROV	12 days	Sun 4/13/25
11	✓	Regional win	0 days	Sat 4/26/25
12	✓	Break	7 days	Sat 4/26/25
13	✓	Fix regional issues	7 days	Sat 5/3/25
14		Making the float	17 days	Sat 5/3/25
15		documentation update	12 days	Mon 5/5/25
16		documentation submission	0 days	Wed 5/21/25
17		Upgrade the ROV	5 days	Mon 5/12/25
18		Test the ROV & float	6 days	Mon 5/19/25
19		Exam break	9 days	Fri 5/23/25
20		Training on the ROV	8 days	Thu 6/5/25
21		Travel to U.S	0 days	Sat 6/14/25
22		The competition	0 days	Thu 6/19/25
23		Winning	0 days	Sat 6/21/25

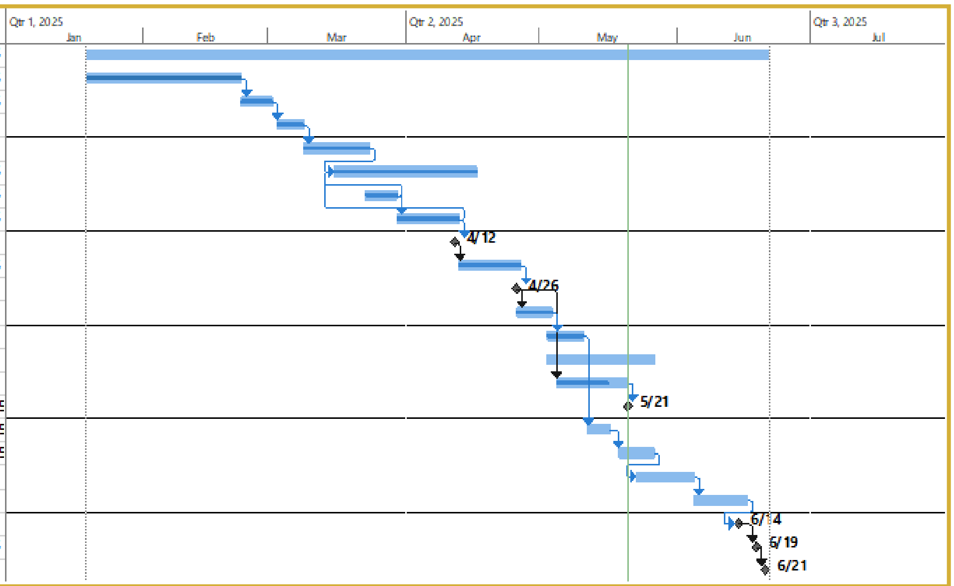

Figure 3 : Company Gantt chart demonstrating the project timeline. Made by Mahmoud Tarek using MS project

1.3 Project Management

From the beginning, clear protocols were set to support teamwork and improve productivity. Leadership roles were assigned during the training phase through board elections led by the mentors to make responsibilities clear from the start. Weekly meetings were held between the CEO and Functional Managers to track progress and plan the next steps. Each department also held regular stand-up meetings to check progress, set short-term goals, and solve daily challenges.

A structured task management system was used to improve efficiency:

Slack: Used for daily communication and regular updates on the team's progress. Tasks were assigned by Functional Managers in dedicated Slack channels using a standard format that included task details, deadlines, assignees, and status.

Notion: Used for task tracking and documentation.

Google Drive: Allowed shared access to important files and collaboration between employees.

GitHub: Used for software development, as it helped manage code, track changes, and support teamwork within the software department.

This organized approach helped the team stay productive, meet deadlines, and maintain smooth coordination across all departments.

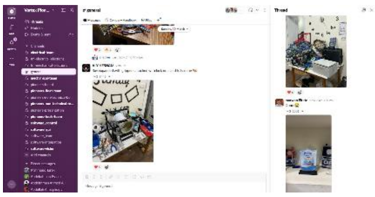

Figure 4 screenshot from our slack main page

2 System design

Since this is our first time participating, we did a lot of research in the data collection phase. Our team has learned a lot about what makes a great ROV. Above all, the best ROVs should be adaptable, easy to control, and built to last. With that in mind, we designed Cronus around three core values: adaptability, simplicity, and reliability.

Figure 5 Full ROV frame structure designed by Mohaned Rafea using SolidWorks

2.1 Vehicle structure

2.1.1 Frame

Regarding the frame, our top priorities were to ensure that Cronus is compact, lightweight, and easily assembled.

While selecting the frame material, we had several options to consider.
We narrowed them down to two main choices: HDPE and Aluminium. Based on testing, we found that HDPE has poor weathering resistance and is prone to stress cracking. As a result, we concluded that aluminium is the better option, as it meets the ROV's requirements more effectively.

Properties	HPDE	Acrylic (PMMA)	Aluminium Extrusions	PLA	Stainless Steel 304
Density (g/Cm^3)	1	1.2	2.7	1.24	8

Impact Strength (J/m)	260	74	294	96.1	325
Flexibility (MPa)	24	71	90	80	540
Cost	Moderate	Low	Moderate	High	Moderate

Table 1 Materials of design comparison

One of the main advantages of the aluminium extrusion is that we can add any payload easily to meet the required tasks just by using a screw and a T-nut we used this method to attach the following(camera enclosures, grippers, main enclosure holder, T200 bracket and the bilges housing brackets) and we can easily modify the aluminium frame by adding aluminium pieces (as shown in the figure 5) connected by 90-degree aluminium angles, and finally we can add any tools easily using snap joints.

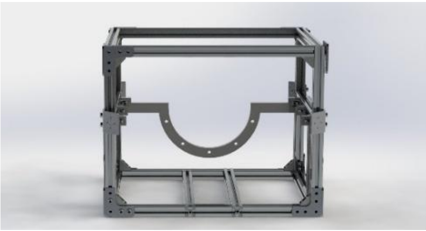

Figure 6 aluminium extrusion structure designed by Mohaned Rafea using SolidWorks

2.2 Main enclosure:

2.2.1 Electronic housing:

Cronus's electronic housing is very special; we chose a cylindrical-shaped enclosure that we chose it instead of a cuboidal-shaped one for the following reasons:

- **Structural Strength and Pressure Resistance**

Spherical shapes use significantly less material due to their stress-distributing capabilities when under pressure, granting them immense suitability for offshore use. The absence of seams results in a lower probability of mechanical failure as stress concentration is minimized.

- **Hydrodynamic Advantages**

Smoother curves enhance power efficiency by minimizing drag when traversing fluids.

- **Thermal Management**

Thermally controlled systems benefit greatly from the even distribution of heat around the shield, which cylindrical structures provide, improving the system's overall thermal management.

- **Easier to Seal**

A round shape makes it easier to create strong, even seals, which is very important for keeping water out of the ROV's electronics.

To take advantage of this feature, we sealed the enclosure from two sides:

One side with a metal sheet of 3 mm to withstand external pressure.

The other side has a circular dome (as shown in figure 6), as the curved geometry according to hydrodynamic principles helps reduce both drag force and pressure by allowing smoother water flow over the surface.

To get more space to add more than one camera and to have better vision for the IP cameras, a dome allows light rays to enter perpendicularly across the entire surface, minimizing refraction and maintaining a consistent field of view underwater.

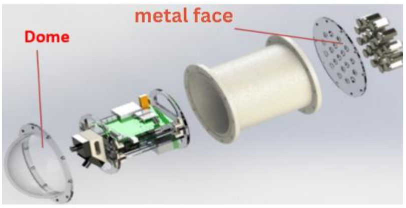

Figure 7 ROV's Exploded view of the electrical enclosure designed by Mohaned Rafea using SolidWorks

2.2.2 Manufacturing of Materials:

Aluminium was used for the outer frame, and links were made using wire CNC machines. PLA used for the fixations of the internal structure was made of a 3D printed material, and Acrylic used in the housing manipulators was cut by a CNC laser machine. Artelon used for the enclosure was cut by manual lathing.

2.2.3 Internal structure

Our internal structure is made of acrylic, and it has 2 shelves (as shown in figure 7); the top layer of the first shelf has five bucks and 2 busbars"48v", the bottom layer of the first shelf has two cytron motor drivers, three video balloons, the second layer of the shelf has the PCB fixed to the shelf.

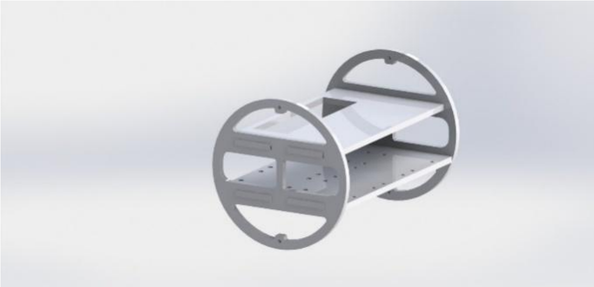

Figure 8 Internal shelves carrying components structure designed by Yousab Youssef using SolidWorks

Before the dome, there is a camera switch attached to it, a 3d part with an IP camera and a CCTV camera are fixed.

2.2.4 Sealing of Enclosure and Cables:

The electrical enclosures are designed with a face-sealing system that uses Nitrile O-rings positioned in machined grooves. When the enclosure is assembled, these O-rings are compressed between the mating surfaces, creating a reliable waterproof barrier. Their selection was based on recommendations from Parker's Sealing Handbook. No additional chemical sealants were applied. To protect against water intrusion through cable entry points, cable glands were installed, effectively isolating the enclosure's interior from external conditions.

3 Propulsion

Using a symmetrical thrust configuration helps with smooth, controlled movements, especially during complex tasks. To have a good field of movement underwater, we agreed on using 8 thrusters: four T-200 Blue Robotics thrusters and four Bilge Pumps. We used two T200 thrusters for the vertical motion(upward and downward), and the other two are placed perpendicular to both sides for forward and backward motion and yawing.

To fix the T200 thrusters, we used a piece of aluminium sheet metal that was cut precisely and attached to the aluminium extrusion from both sides using screws and t-nuts, (as shown in Figure 8).

Figure 9 bilge pump fixation to Cronus's frame structure designed by Mohaned Rafea using SolidWorks.

The four Bilge Pumps are for lateral motion only. The four of them were attached by a 45-degree angle (as shown in Figure 9) , which gives Cronus a degree of freedom and provides better lateral motion.

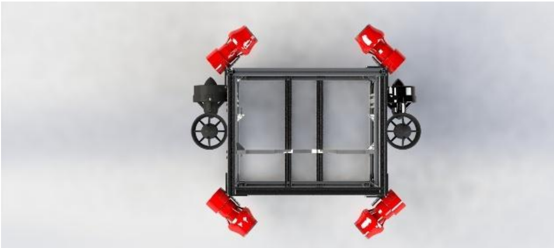

Figure 10 frame and motors fixation structure designed by Mohaned Rafea using SolidWorks

The angle of 45 degrees was chosen as it was the best angle while testing through flow simulations.

4 Stability and Buoyancy:

For best stability and buoyancy performance, the structural frame of the ROV was designed with a wide base to increase lateral stability and rolling moment resistance. Several ballast weights were placed at the bottom of the frame to reduce the Centre of Gravity (CG), which increases the righting moment and overall stability of the system. This system also supports the general principles of marine engineering, which require a low CG of the buoy in static equilibrium with the centre of buoyancy (CB).

Also, the positive impact of the vehicle's buoyancy characteristics was obtained from the watertight enclosure used for the sensitive electronics because it houses. Its composition materials are also buoyant, giving it a position of elevation to the CG while being located at the top section of the ROV. Hence, this aids in lifting the CB. This increase causes an enhanced restoring torque when external disturbances like currents or imbalances in the thrusters are experienced, which aids in self-righting behaviour.

These approaches follow the steadiness of the underwater vehicle's guide and the control documents by Thor I. Fossen and are guided by the Society for Underwater Technology (SUT) standards.

5 Control/Electrical system:

5.1 The Electrical System

5.1.1 The Tether

Our tether is 25 meters that contains a power cable 2 cores of 12 AWG that minimizes voltage drop and does not affect the ROV's power consumption significantly, three CAT6E Ethernet connected with RJ connector by cross over method to minimize the noise cables configured as follows one for communication "Ethernet w5500 module to the station ", one to link the IP cameras switch to the station, one to connect CCTV cameras to the station and two pneumatic cables for the horizontal and verticalgrippers.

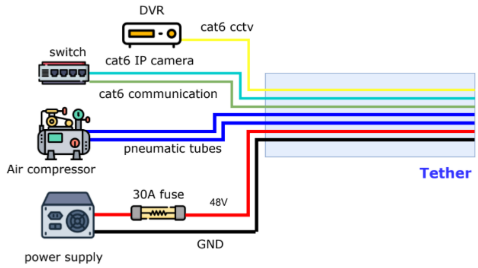

Figure 11: Tether management diagram designed by Mariam El seikly using draw.io

To improve reliability, we added a Protective Sheath for Waterproofing & Durability.

Check Appendix C for the tether management protocol.

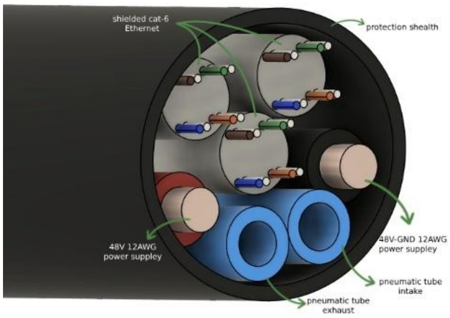

Figure 12: Tether 3D cross-section designed by Amr Barghash using AutoDesk fusion

5.1.2 Top side "Station"

The topside control system consists of two laptops powered directly from a standard 220V AC source. The first laptop is connected to a joystick to control the ROV. Communication with the ROV's Arduino is established using an SPI module (W5500) connected via a CAT6 Ethernet cable to a network switch. Four IP cameras on the ROV are also connected to the same switch using a CAT6 cable. The switch is then connected to both laptops (as shown in figure 12), allowing them to communicate with the Arduino and display live feeds from the IP cameras. In addition, a monitor is used to display footage from the three CCTV cameras. These cameras are connected to a DVR through a CAT6 cable, and the DVR is directly connected to the monitor, providing real-time visuals of the ROV's surroundings. Power for the entire ROV system

is supplied through a 48V 30A power supply, which is also powered from the AC source.

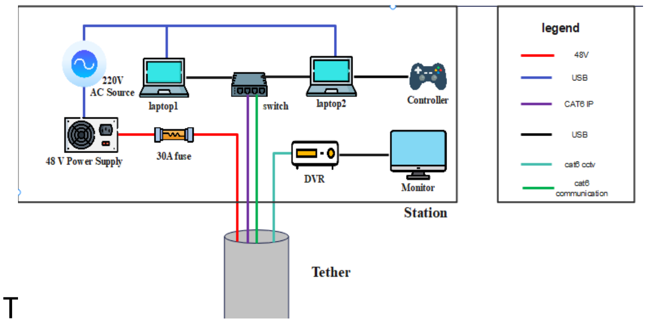

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Figure 13: Top-side station diagram made by Mariam El seikly using EdrawMax

Power Calculations

The power supplied at the station is 48V*30A=1440 watts; the ROV's power consumption cannot exceed this, taking into consideration the power lost in the tether.

Power Lost By the Tether

The resistance of the tether can be calculated by the formula R = (ρL)/A

ρ = Resistivity of copper ≈ 1.72×10^{-8} Ω·m,

L=Total length = 2x25 = 50 meters,

A = the cross-sectional Area = 4×10^{-6} m^2

The resistance is 0.215 ohms, so the power lost by the tether can be calculated by the formula $Pw = I^2 * R = 30^2 * 0.215 = 193.5$ watts. Therefore, the maximum power the ROV can consume is 1246.5 watts.

The ROV's Power Calculation

Power Calculation Table:

Power Calculations					
Category	Component	Quantity	Voltage	Current	Power
Motion	T200(Motor)	2	12	10	240
	Bilge Pump	4	12	7.5	360
Tools	DCV	2	12	0.4	9.6
	LED	1	12	4.17	50
	Valve	1	12	2	24
Control	Arduino+Sensors	5	5-3.3	0.45	2.25
	Cameras	7	12	1	84
	Switch	1	48	0.8	38
	Fan	2	12	0.2	4.8
				Total	**812.65**

Table 2 Power calculations table

After doing the required calculations, the maximum power that can be consumed by the ROV is 812.65 watts, which is way less than the power that the station can supply after deducting the power consumed by the tether.

5.1.3 The ROV Internal Structure

The Internal Structure, as clarified in the SID, consists of 5 main 48V/12V up to 20A buck converters. We are using two buck converters to supply power to four T200 thrusters, and they are connected in parallel. Each buck converter supplies two thrusters, one for vertical movement and one for horizontal movement. We will only activate one thruster per buck converter, either the vertical or the horizontal. This allows the full power output to be dedicated to the active thruster, ensuring maximum performance when needed. And two buck converters are each connected to a dual-channel Cytron motor driver. The last buck converter is connected to the system's PCB, which powers various tools, such as DCVs, a valve, CCTV cameras, and LEDs, through MOSFETs. This PCB also supplies power to components like the Arduino Mega, Ethernet W5500 SPI module, ESP-01, pressure sensor, IMU, and I2C level converters.

"Check Electrical SID in Appendix "

The PCB

We designed a custom PCB to manage power distribution and signal connections of our system efficiently and without taking up too much space. It is a double-layer board (as shown in figure 13) with a thickness of 1.6mm and a 2-oz copper layer to be able to withstand high current. The PCB is responsible for handling communication between the Arduino Mega and the sensors, modules, and motor drivers. It takes 12V power through 3 XT60s. Two of the XT60s power the ESCs, which are responsible for controlling the thrusters, and the last XT60 powers the system. We added a 12V to 5V buck converter that takes the 12V power from the later XT60 and powers the sensors and modules.

Figure 14: PCB 3D model designed by Philopater Tarek using Altiumdesigner

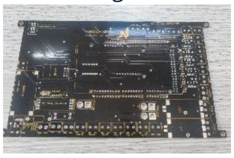

Figure 15 PCB picture shot by Mahmoud Tarek

The PCB connects to sensors like the pH sensor, pressure sensor, and IMU, allowing the Arduino to read real-time data from the environment to make our ROV able to do specific tasks underwater.

The ESP-01 WIFI module and SPI Ethernet module are integrated into the PCB for potential wireless communication. We added an I2C Blue Robotics level converter to connect the pressure and IMU sensors. It's hard to find a spare one in Egypt as there are no suppliers, and the module is expensive, so we decided to add a level shifter, which is available locally, to work as a spare for the I2C level converter.

While designing the PCB, we wanted to make it a general-purpose board that could be useful for future projects, so we added spare pins for the Arduino Mega, allowing us to connect extra components or sensors later if needed.

Although our current ROV design uses four bilge pump motors, we included six motor inputs on the PCB. This gives us the option to add extra motors in the future if more thrust or higher speed is needed.

Schematic Layout

To allow all of us to share their work and divide it professionally, we divided our schematic files into five schematics: power, signals, motors, sensors, communication, and safety.

Each file is designed individually and then integrated into the main schematic file named "system" (as shown in Figure 14).

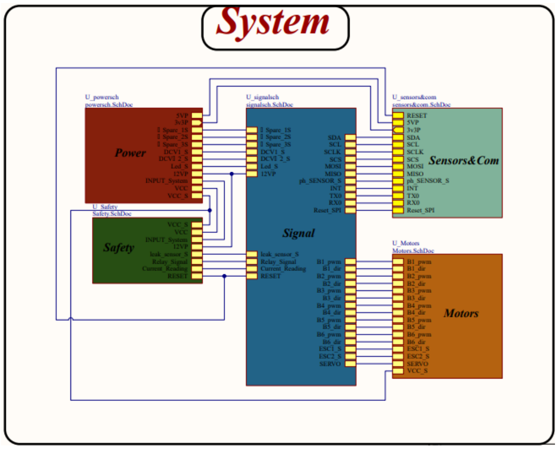

Figure 16: System schematic diagram Designed by electrical team using Altium designer

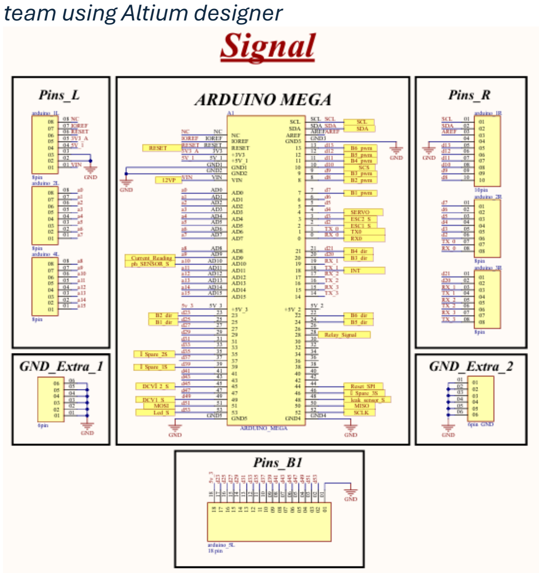

Figure 17 Signal schematic designed by Amr Barghash using Altium designer

5.2 Control

5.2.1 Hardware selection

During the consideration of computing units for the execution of system control, the Arduino Mega was selected as the central processing unit. The primary reasons for this selection are:

- A high number of I/O pins.
- Technical handling and integration simplicity.
- Reusability from a past project, promoting sustainability and affordability.

For better accessibility and ease of maintenance, we interface the Arduino Mega with an ESP-01 Wi-Fi module. Using the ESP-Link firmware, the ESP-01 is used as a Wi-Fi___33-to-Serial bridge, enabling Over-The-Air (OTA) firmware flashing and updates. This eliminates the need to physically access the board for debugging, avoiding repetitive opening and resealing of the enclosure.

Communication Module Selection,

After a careful comparison (see Table 3), we selected the W5500 Ethernet module over the RS-485 serial communication module for Cronus. The W5500 offers:

- High data transmission rate (up to 100 Mbps).
- Full-duplex communication via SPI.
- Direct connection to laptops via Ethernet, without requiring an external topside interface.

As a comparison, RS-485, while perfect for long-distance and noise-tolerant communication, is only able to offer half-duplex data communication and requires additional components like termination resistors and a topside communications unit.

Feature	W5500 (Ethernet Module)	RS-485 (Serial Communication)
Speed	Up to 100 Mbps	Up to 10 Mbps
Transfer Type	full duplex (Ethernet TCP/IP)	half-duplex (asynchronous serial communication)
Pros	High-speed, stable, supports networking	Long-distance, noise-resistant
Cons	Requires Ethernet cables and a networking setup, with higher power consumption	Half-duplex requires additional wiring and termination resistors for long distances.

Table 3: Trade-off between Ethernet module and RS-485

5.2.2 Software Control System

The Cronus control system effectively translates pilot commands into precise motor commands while processing sensor feedback for stabilization at the same time.

Communication Protocol

Communication with the surface station (server) is enabled by the Arduino Mega (client) using Python-based socket programming over SPI. The Pygame library is utilized for reading joystick inputs and mapping them to corresponding ROV functions.

Commands are encoded into formatted, fixed-length messages and reliably transmitted to Cronus.

The Arduino decodes incoming signals and enables real-time actuation of thrusters, grippers, servos, and ballast systems.

Feedback Sensing and Stabilization

Cronus employs several sensors for telemetry and control:

- Bar30 Pressure Sensor: Depth is monitored in real time.
- MPU-9250 IMU: Stability and orientation are preserved.
- All other telemetry (pressure, pH, IMU, and leak detection) is transmitted in formatted strings and is shown on the pilot's GUI (as shown in Figure 16).

Figure 18: Pilot's user interface

5.2.3 Control Box

Control Box provides power and offers an interface to the MATE competition standard. It is powered from a 110V AC wall outlet and provides 48V DC to the ROV via a 25-meter tether. The key features are:

Power Components:

- Four AC-DC power supplies.
- Each convert 110VAC to 12V at 30A.
- Connected in series to provide 48V at 30A, for a total of 1440W.

Safety and Monitoring:

- Emergency cutoff switch.
- LCD wattage meter to display voltage, current, and power in real time.
- Anderson connectors and an additional AC outlet.

Internal Wiring:

- High-current screw terminals with wires of 10–12 AWG.
- All the components are well arranged to prevent exposed wires and reduce electrical hazards.
- Contained within a hard plastic case for mechanical protection.

6 Payload and tools

6.1 Computer vision

Camera Layout

We implemented a custom camera system to support both navigation and mission-critical imaging. Our vision system consists of 4 High-Resolution IP Cameras and 3 CCTV Cameras. Where IP cameras were new, and CCTV ones were reused.

• Front: Two cameras— one IP camera for the main view, one CCTV camera facing the horizontal gripper.

• Frontal enclosure: Three cameras—one CCTV camera facing the sample collection tool to help see the 1-meter launch square, one CCTV camera facing the vertical gripper, and two IP cameras to complete a full 360-degree field of view.

• Bottom centre: A downward-facing camera for precise positioning and measurement tasks.

(These views are shown in Figure 17)

Figure 19 Camera cones showing camera views , designed by Mohamed Rafea using SolidWorks

IP cameras were used in photosphere construction due to their wide angle, which allows us to use only two cameras to cover Cronus's field of view. Additionally, due to its high quality, using an IP camera was a perfect solution for determining shipwreck length tasks. All IP cameras are routed through a single PoE switch, simplifying the tether layout while maintaining stable power and data flow throughout the mission.

Criteria	Multiple IP Cameras	Single 360° Fisheye Camera
Resolution	High	Low
Setup Size	Large / Bulky	Compact
Wiring complexity	High	Low
Setup Size	Large / Bulky	Compact
Image Distortion	Minimal	High (especially at edges)
Lighting Sensitivity	Better (individual sensor tuning)	Poor (struggles in low light)

Table 4: Trade-off between using multiple IP cameras vs using a single 360 Fisheye camera for the photosphere mission

Streaming

For real-time video streaming, low-latency and high-quality feeds for the pilot, we use GStreamer pipelines. RTSP streaming for IP cameras is enabled for customizability and to be able to work on multiple laptops, ensuring uninterrupted video feeds.

Calibration

Chessboard-based calibration board is used to correct distortion from wide-angle IP cameras, ensuring precise image mapping and navigation accuracy.

For real-time video streaming, low-latency and high-quality feeds for the pilot, we use GStreamer pipelines. RTSP streaming for IP cameras is enabled for customizability and to be able to work on multiple laptops, ensuring uninterrupted video feeds. Chessboard-based calibration board is used to correct distortion from wide-angle IP cameras, ensuring precise image mapping and navigation accuracy. Calibration data is pre-stored and applied in real-time to maintain consistency and reliability throughout the mission, by giving specific OpenCV libraries the real-world dimensions of the chessboard and capturing a variety and different angled photos.

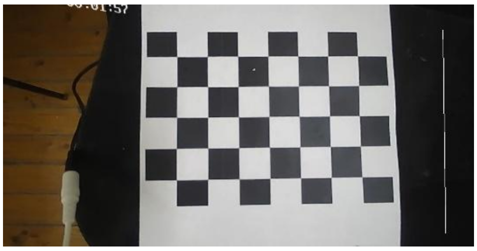

Figure 20 Chessboard image after calibration

Photosphere 360° Construction Utilizing PTGui, which is a commercial high-precision stitching tool that helped us produce high-quality panoramas which proved superiority over Hugin, which was our alternative.

Criteria	PTGui	Hugin
Advantages	GUI-driven Better lens profile control	Free and open source Flexible with scripting
Speed	Fast	Slower
Learning Curve	Steeper; requires time to master	Easier to start; scripting adds complexity
Batch Processing	Highly optimized for large batches	Less efficient; struggles with large batch jobs
Stability	Very stable	May become unstable under heavy processing

Table 5: Trade-off between using PTGUI and Hugin, which are two software programs for generating 360° photosphere

Measurement

As per the requirements of Task 1.1 Shipwrecks, after the pilot successfully manoeuvres the ROV to position itself above the shipwreck, a frame will be captured from the downward-facing IP camera. To maximize accuracy and avoid point deductions from having an error greater than 5 cm or 10 cm, the ½-inch PVC pipes marking the bow and stern of the shipwreck, along with the Aruco marker will be placed on the same plane. This setup ensures proper perspective alignment and significantly reduces distortion-related errors, resulting in a more reliable measurement.

Once the frame is captured, our script is executed, which uses OpenCV's Aruco marker detection libraries. The Aruco marker, a printed square fiducial with known physical dimensions, acts as a scale reference. By detecting the Aruco marker and using its known size in centimetres, the algorithm computes a pixel-to-real-world scaling factor.

Using this factor, the script then measures the distance in pixels between the front of the bow PVC and the back of the stern PVC as seen in the frame. This pixel distance is converted into centimetres based on the scaling derived from the Aruco marker, yielding the true estimated length of the shipwreck.

This final measurement will be verbally communicated to the station judge as required by the task guidelines.

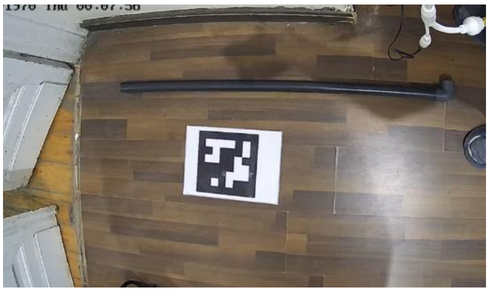

Figure 21 Uncalibrated image taken from an IP camera

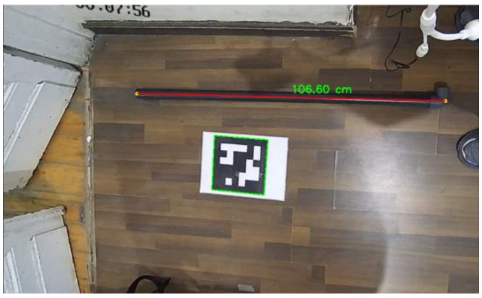

Figure 22 Calibrated camera with real-life measurement of a PVC pipe with a reference of an Aruco marker (Real length is 106.5 cm)

6.2 Tools

6.2.1 Manipulators (Grippers)

To accomplish various mission tasks, *Cronus* is equipped with two custom-designed grippers:

- **Vertical Gripper:** Designed specifically for the *Shipwrecks 1.1* mission, it is used to remove covers efficiently.
- **Horizontal Gripper:** Serves general-purpose manipulation tasks, such as grasping and moving objects.

Both grippers were designed using CAD and fabricated from acrylic, offering a lightweight, strong, and corrosion-resistant solution. Their integration enhances task precision and reduces operation time, supporting effective underwater restoration and exploration.

Figure 23 Grippers multipurpose tool Designed by Mohamed Rafea using SolidWorks

6.2.2 Snap Joints

Custom 3D-printed snap joints (Figure 20) were developed to attach tools securely to the ROV's aluminum extrusion frame. These snap joints enable quick tool swapping during trials and missions, significantly improving operational flexibility and efficiency.

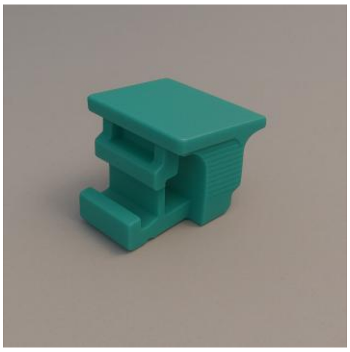

Figure 24 Snap joints used to attach tools to the aluminium extrusion designed by Mohamed Rafea using SolidWorks

6.2.3 Sample Collection Tool

Initial prototypes using a metal tube and water pump were ineffective due to pressure challenges encountered at depth. Inspired by the pressure-induced leakage behaviour in enclosures, we implemented a design based on **pressure differential physics**:

- A **large syringe** (at atmospheric pressure) is connected to a **metal tube** that penetrates the barrel's opening.
- A **normally closed solenoid valve**, controlled via a **MOSFET**, regulates sample intake.
- When the tube is inserted into the barrel and the valve opens, the **external water pressure** (higher than the syringe pressure) causes the fluid sample to flow into the syringe.

This design is simple, robust, low-maintenance, and effective at depth.

Figure 25 Sample collection tool used to take the PH sample , shot by Abdullah Fawzy

6.2.4 Polyp Stage Jellyfish Collector

Early designs using a fork-shaped hook resulted in jellyfish polyp simulants detaching during retrieval due to water drag. Upon discovering the embedded metal inside the *chenille strips* (used to simulate polyps), we revised the design:

- A **strong magnet** was integrated at the tips of the **acrylic fork-shaped hook** (Figure 23).

This magnetic enhancement ensures secure collection and transportation of polyps with minimal risk of loss.

Figure 26 Polyp stage jelly Fish collector designed by Mohamed Rafea using SolidWorks

6.2.5 Fish Species Collector

To collect ping pong balls simulating fish species beneath the solar panel array:

- A **PVC frame** resembling a mini soccer goal was constructed and mounted to the main ROV frame using **snap joints** (Figure 24).
- A **tip feature** was added to prevent the balls from escaping once collected.

This net-based tool enables Cronus to efficiently gather all target balls while maintaining manoeuvrability and stability.

Figure 27 Fish Spiece collector designed by Mohaned Rafea using SolidWorks

6.3 Build vs. Buy Analysis

Throughout the development of *Cronus*, a "build over buy" philosophy guided our engineering decisions. Except for a few critical off-the-shelf components like the solenoid valve, all major tools and mechanisms—such as the grippers, jellyfish collector, fish collector, and sample collection system—were fully custom-designed and fabricated in-house. This approach allowed greater control over functionality, weight, cost, and mission-specific adaptability, while also encouraging innovation, problem-solving, and efficient resource use.

6.4 Innovation

One of your most significant innovations is the use of bilge pumps with our specially made housing. As a result, we could accomplish the same functionality as T200 thrusters at a lower cost.

Two T200 thrusters are represented by four bilges positioned at 45-degree angles.

Four bilges and their housing cost nearly one-eighth of the cost of two T200 thrusters.

The most creative was the sample suction tool, which we created from the ground up. It is this year's most important tool due to the point dependencies. Since we discovered that none of the other teams employed a similar technique to collect samples—the majority of them used a standard water pump—our approach differs significantly from theirs.

6.5 Problem Solving

Before initiating the development of the ROV, our team underwent a dedicated brainstorming phase. As Titans, we believe that innovative ideas emerge through collaboration rather than individual effort. One member may offer a spark of insight, which others build upon, adding their perspectives and expertise, until we collectively arrive at a well-developed, practical solution. This process ensures that our concepts are not only creative but also aligned with functional requirements and safety standards. Additionally, we often refer to past TDRs to gain insight into how other teams approached similar challenges, helping us broaden our thinking and refine our ideas.

Our team evaluates alternatives using a logical, data-driven process in addition to brainstorming. Following the generation of several possible solutions, we carry out trade studies to evaluate options according to important criteria like cost, performance, ease of integration, safety, and feasibility.

We make sure the chosen design path is not only creative but also best suited for the particular mission requirements by allocating weighted criteria and evaluating both quantitative and qualitative data. Throughout the course of the project, this systematic decision-making process reduces risk and maximizes efficiency.

7 Critical analysis

As Titans, we need to ensure that the workflow does not get disrupted and minimize future problems, and to figure out the cause of any problem that we face and resolve it in the shortest possible time, We follow simple sequential steps to achieve that.

7.1 Testing Methodology

Our Testing Methodology aims to achieve certain goals

1.Ensuring that each propulsion, payload, or tool is working fully functional separately before integration.

2.Conducting several tests to ensure that, after integration, the performance is not affected.

3.Lastly, make sure that it will fulfill our safety measures and will be capable of doing the required missions during the product demonstration.

7.1.1 Mechanical Testing

1.Sealing: one of the most important tests that is conducted, the sealing test, as Cronus maneuvers at a depth of 5 meters, so we need to make sure that it does not leak due to the high pressure difference. This test was conducted by applying an inner pressure of 0.5 bar and placing the enclosure in water with soap, and observing the source of the leakage in the form of bubbles.

2.Buoyancy and Stability: Cronus undergoes controlled buoyancy tests to ensure weight distribution and align the center of gravity with the center of buoyancy, achieving neutral buoyancy. To ensure that the system remains stable under all situations underwater.

3.Thruster Force: As we use bilge pumps, which are not mainly manufactured to be thrusters, we perform several tests on our bilge pumps with our housing design (as shown in figure 25). Also, to avoid multiple losses, we 3D print one housing and install it, then test individually after we make sure it is efficient, we place an order with the rest.

Figure 28 Bilge pump housing

Electrical Testing

1.Continuity Test: continuity mode, which is found in the Avometer, we use it for two main tests. The first is to ensure that there are no short circuits present due to soldering, and the second is to ensure that there is a common ground in our system.

2.Pre-internal Test: Before we add any component to the internal system, we must be sure that it supplies the required power, not more or less, to avoid performance drop or damage

Software Testing:

1.**Module-based testing and debugging:** Our ROV's system is divided into different modules, each of which is tested and debugged separately to increase testing efficiency.

2.Integration testing: We combined the modules and ran tests after adding each module to the system to put our hand fastly on the module that is causing an integration problem.

7.2 Troubleshooting

To ensure system reliability and minimize the risk of errors, we implemented a structured and efficient troubleshooting approach. Our methodology focuses on narrowing down the potential causes of an issue by systematically isolating and analyzing each component until the root problem is identified. This step-by-step process prevents the escalation of problems and reduces the chance of introducing new complications.

By breaking down complex issues into their most basic, indivisible elements, we can address problems with precision. This disciplined approach enhances our ability to resolve technical challenges quickly and effectively while maintaining the overall integrity and performance of the system.

And follow these steps :

1.Identification: When an issue is detected, we meticulously trace it to its root cause. Once identified, we isolate the problem from the main system (Cronus) to prevent further complications and to facilitate focused troubleshooting.

2.CauseAnalysis: After pinpointing the issue, we conduct a thorough investigation to determine its underlying cause. To validate the suspected cause, we perform additional tests to eliminate other potential factors and ensure accuracy in diagnosis.

3.SolutionDevelopment: Once the true cause is confirmed, we proceed with implementing the most suitable solution. We also evaluate alternative approaches to ensure they comply with our budget constraints and safety standards, selecting the one that offers the best balance of reliability, cost-efficiency, and system compatibility.

Practical Example: IMU Gyroscope Sensor Failure

Let's consider a scenario where our IMU gyroscope sensor unexpectedly stops functioning. In such a case, members from both the electrical and software teams collaborate to diagnose and resolve the issue efficiently by systematically narrowing down the possible causes.

Step1: Hardware Inspection

The electrical team begins by carefully removing the sensor from the PCB. They inspect each pin for continuity and check the module for any visible signs of damage. To further isolate the issue, they connect the sensor to an external Arduino board, ensuring the wiring and circuit are correctly configured.

Step2: Functional Testing
Next, the software team runs a standard example script—typically from the sensor's official library—to verify whether the sensor operates as expected.

- **If the sensor fails to respond**, the issue likely lies within the sensor itself.
- **If it functions correctly**, attention shifts back to the PCB.

Step 3: PCB and Power Verification
At this point, the electrical team confirms that the PCB is supplying the correct power to the sensor and that the signal lines are properly connected and functioning.

Step 4: Integration Code Review
If all hardware-related checks are passed and the sensor operates externally, the issue almost certainly lies within the system's integration code. The software team then inspects and debugs the relevant sections to resolve the conflict.

8 Safety

8.1 Safety System

Our Safety Philosophy

Safety is our top priority at our company. Our philosophy is to provide a safe environment and ROV; to ensure the safety of the members debugging on the ROV and the ROV assistant during the product demonstration. A non-safe environment and ROV are unusable, so we are strictly following our safety protocols.

Safety Training

Before we even started building or working on the ROV, we had safety training. All team members got trained to use the equipment safely and follow safety rules. Training started with an introduction about risks, emergency steps, and how to use the tools. After that, we practiced under supervision to learn safe habits in real situations. We also regularly review safety and do drills to make sure everyone stays prepared and informed.

Our Task Handling Safety Protocol

Each task has a hazard rating from 1 to 3, where 1 is a hazardous task that requires following the safety measures: The functions that have this rating are (drilling, pneumatic testing, cutting using the Grinder, soldering electronics, cables, etc). These Tasks are done in a certain room specialized for hazardous tasks. No one is allowed to enter this room when performing these tasks except the members required to perform them. This room is equipped with the required tools and the safety equipment (Safety gloves and goggles) that must be used in this room,(as shown in Figure 26) .In addition, there is an emergency aid kit in case of any emergency.

Figure 29 Following safety protocols captured by Mahmoud Tarek

Tasks with a hazardous rating of 2, like debugging the ROV, opening the internal structure, and making electrical or mechanical modifications to the ROV, all similar tasks, are done on the operation table.

The only members who can stand by the table are the members assigned these tasks, the power supply is far from the table and disconnected, while debugging to ensure nothing happens to the ROV, and to provide a safe environment for the members. Tasks with a hazardous rating of 3 are mainly software and non-technical work, which is done in a separate room far from the hazardous tasks room and the operation table. To ensure a safe environment.

The Mechanical Safety of the ROV

To ensure the ROV is safe for the mechanical team when performing certain tasks on the ROV and the ROV assistant during the product demonstration, mechanical safety measures are taken in consideration, any sharp edges should be covered like the head of the nylon cable ties should be covered by glue, a capnut should cover any screw end and the terminals of the aluminium extrusion is covered by a 3d part as the terminals are sharp. Moving parts should be covered, we have two major moving parts: T200 thrusters and bilge pumps motor housing. The T200 thrusters are covered with an aluminium mesh, and the bilge housing is covered with a 3D printed mesh (as shown IN figure 27).

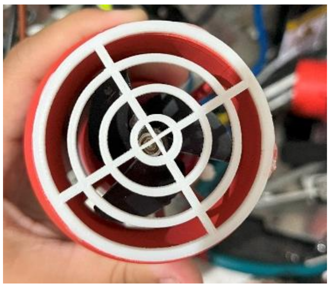

Figure 30 Bilge pump 3D printed mesh to ensure safety shot by Sarah Ateya

These moving parts are covered following the IP-20 standards.

The Electrical Safety of the ROV

We use Anderson SBS50 connectors on our ROV because they can withstand high current loads, lock with a secure latch, and withstand harsh environments. To guard the power system, we employed fuses designed for a maximum estimated current of 17A with a 1.5× safety margin, so we had a 25A on the main tether and 15A on the PCB, which protected the more sensitive parts, ensuring component safety. This configuration defends against overcurrent and short circuit simultaneously. We selected a minimum of 12 AWG cables to contain the heat and current safely. Along with marine electrical grade fuse boxes and waterproofing the vessel, our design provides unparalleled electrical safety intended for submerged applications.

Accounting

Given that it was our initial year in the Pioneers class as well as our first time participating in MATE, it was quite difficult to create a precise budget for our Cronus ROV. Such as we needed to estimate the budget. For this, we looked up older data from previous Explorers and Rangers teams, as they provided a better framework since most basic parts are the same throughout all the categories. This data served as a sound basis for our finances.

As a first step, we looked up how older ROVs could be reused for components in Cronus ROVs, which aids our primary goal of minimal expenditures. To our surprise, several components like the two T200 thrusters, ESCs, DC-DC converters, Bar30 pressure sensor, and many power, Ethernet, and pneumatic cables were in quite good shape. One other such item was an 8-channel DVR, which continued to function properly along with Agro glands, DCVs, and numerous fittings. Because these components are considered DCVs, the lifetime expectancy is rather durable. Such components enabled us to save up over (number) dollars. Not only did they aid us in achieving the goal but assisted in minimizing the overall expenditure.

Revisions needed to be made to guarantee the utmost functionality of the system. We took out Sailingflo bilge pumps, replacing them with Xylem's Rule bilge pumps to take full advantage

of their thrust control, while also adding two new Cytron dual-channel motor
drivers for improved thrust after the control.
For improved navigation, we added a new MPU sensor and IP and CCTV cameras for better visibility in low and reduced light areas.
On the control side, we integrated an Ethernet module into the Arduino Mega, designed and fabricated custom PCBs, and purchased a new joystick with various connectors, video baluns, aluminium profiles, PMMA, and multiple 3D printed parts, which improved overall stability and structure.
Our local community served as a critical source of support and inspiration. While presenting at 3D Max Entity in Alexandria, we showcased our project, and they provided a $250 high-resolution screen for the control station. This gift reinforced the team's morale while proving to be a meaningful aid.
While progressing, we replaced two additional thrusters and purchased two new ESCs to accommodate them after winning the regional competition in Egypt and qualifying for the International Championship. We also refurbished the old housing for the bilge thrusters with a new lightweight, durable version to improve ease of maintenance, water resistance, and reduce weight.
In summary, although our budget limit was set at (number), with effective planning and strategic resourcefulness, we managed our actual expenses to (number). This figure resulted in a surplus of (number). This amount will be applied to initiate the development plan for next year, allowing us to sustain our growth and continue pioneering advancement

Type	Category	Expense	Description	Source	Amount	Running Balance
Re-used	Electronics	cable	power cable (30m)	elsewedy electric	$45.30	$4,554.70
Re-used	Electronics	pneumatic cable	pneumatic cable(32m)	local shop	$22.30	$4,532.40
Purchased	Electronics	cat 6	cat 6 (30m)	elsewedy electric	$45.60	$4,486.80
Re-used	Electronics	buck	15ADC-DC buck	Makers	$25.75	$4,461.05
Re-used	Electronics	4*Thrusters	T200 motors	Bluerobotics	$1,000.00	$3,461.05
Re-used	Electronics	motor driver	Four ESC	Bluerobotics	$76.00	$3,385.05
Purchased	Electronics	motor	1100GPH biges pumps 4 uints	Future electronics	$300.00	$3,085.05
Purchased	Electronics	motor driver	Cytron motor driver	Future electronics	$56.00	$3,029.05
Purchased	Sensors	sensor	Ph sensor	Bluerobotics	$35.00	$2,994.05
Purchased	Sensors	sensor	MPU GY-6500 6axis	Makers	$6.00	$2,988.05
Purchased	Electronics	micro controller	Arduino mega	Makers	$30.00	$2,958.05
Purchased	Electronics	Comuincation module	Ethernet SPI	Makers	$12.00	$2,946.05
Purchased	Electronics	Comuincation module	ESP 32	Makers	$3.00	$2,943.05
Purchased	Electronics	buck	20 A buck(5 uints)	Makers	$60.00	$2,883.05
Purchased	Electronics	DCV	dcv(2 uints)	local shop	$60.00	$2,823.05
Purchased	Electronics	Switch	Camera switch	hikvision	$40.00	$2,783.05
Purchased	Electronics	connectors	terminal blocks, pin headers,terminals cables	Makers	$40.00	$2,743.05
Purchased	Electronics	PCB	Main pcb	Pcbway	$40.00	$2,703.05
Purchased	visual	Cameras	IP cameras(4 units)	hikvision	$66.00	$2,637.05
Purchased	visual	Cameras	CCTV (3 units)	hikvision	$50.00	$2,587.05
Purchased	Electronics	PCB	Backup pcb(4 uints)	Pcbway	$160.00	$2,427.05
Re-used	Electronics	Power Supply	Power Supply 48v	Makers	$82.00	$2,345.05
Re-used	Sensors	Pressure sensor	Bar 30 Pressure sensor	Bluerobotics	$85.00	$2,260.05
Donated	visual	screen	control panel screen	local shop	$220.00	$2,040.05
Purchased	Electronics	joy stick	Xbox joystick	Xbox	$72.00	$1,968.05
Re-used	Hardware	case	control panel case	local shop	$134.00	$1,834.05
Re-used	Electronics	DVR	8 channels dvr	local shop	$112.00	$1,722.05
Purchased	Hardware	accessories	case accessories	local shop	$35.00	$1,687.05
Purchased	Electronics	connectors	video baluns(6uints)	local shop	$8.00	$1,679.05
Purchased	Hardware	enclousure	Main enclousre matrial(PMMA&PA type 6)	local shop	$190.00	$1,489.05
Purchased	Hardware	Extrution	Aluminum Extrution	local shop	$122.00	$1,367.05
Purchased	Hardware	enclousure	camera enclousre(face Seal)	local shop	$80.00	$1,287.05
Purchased	Hardware	enclousure	camera enclousre(piston seal)	local shop	$35.00	$1,252.05
Purchased	Hardware	support	L,T fittings	local shop	$8.00	$1,244.05
Purchased	Hardware	support	camera Angles	local shop	$33.30	$1,210.75
Re-used	Hardware	enclousure	DOM	local shop	$72.00	$1,138.75
Purchased	Hardware	enclousure	U enclosure	local shop	$112.00	$1,026.75
Purchased	Hardware	plugs	plugs	local shop	$22.00	$1,004.75
Purchased	Hardware	grippers	grippers material (PMMA)	local shop	$41.00	$963.75
Purchased	Hardware	grippers	grippers munfacturing(laser-cutting)	local shop	$29.00	$934.75
Purchased	Hardware	propler	propler thrusters	local shop	$35.00	$899.75
Purchased	Hardware	enclousure	Gland face	local shop	$150.00	$749.75
Purchased	Hardware	fittings	T nuts-screws	local shop	$70.00	$679.75
Re-used	Hardware	Glands	Agro glands	local shop	$128.00	$551.75
Purchased	Hardware	O-Rings	O-rings for enclousure	local shop	$5.60	$546.15
Re-used	Hardware	pistons	Pneumatic pistons for grippers	local shop	$48.00	$498.15
Re-used	Hardware	fittings	fittings for Rov fram	local shop	$32.00	$466.15
Purchased	Hardware	3D prting	3d parts for thrusters and camera support	local shop	$112.00	$354.15
Purchased	Hardware	Mesh	thrusters mesh	local shop	$20.00	$334.15
Purchased	travel	Travelling	tarvelling and shipping ROV	shipping company	$1,000.00	-$665.85
Purchased	travel	shipping	shipping cost for imported items	shipping company	$20.00	-$685.85
Purchased	competition preparation	traning	prop buliding	local shop	$200.00	-$885.85
Purchased	logstics	traning	traning villa place	local shop	$400.00	-$1,285.85
Donated	donatians	workshop	donation for preparing the workshop	collage	$250.00	-$1,035.85

Table 6 Accountic table

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2025 Competition manual, pioneer class. 2025 MATE Competition Manual Page Covers.

Table 7: Budget planning

9 Appendix

9.1 Appendix A: Safety checklist

1. Safety Checks Before Deployment

- ☐ Check the tether for any cuts, tears, or weak points
- ☐ All electrical connections must be checked for proper tightness.
- ☐ Power System: Check that the voltage and current are within the acceptable limits.
- ☐ Check the wire insulation for any signs of wear or damage.
- ☐ All bolts, fasteners, and frame components must be tightened to ensure the structure is sound.
- ☐ Thruster functionality: Check for obstacles and usability.
- ☐ Check that the sensor is operating and transmitting data correctly.
- ☐ Adjust the buoyancy to maintain exact neutral buoyancy.

- ☐ Emergency Detachment: Check that release systems are functioning correctly.

2. Checks for Operational Safety

- ☐ Emergency Readiness: Every crew member must be aware of the shutdown procedures.
- ☐ Keep your hands and clothes away from moving parts for your own safety.
- ☐ Power Monitoring: Monitor power usage to prevent overloads.
- ☐ Real-time communication between the surface team and the pilot cooperation.
- ☐ Practice tether management to avoid entanglement and excessive tension.
- ☐ Environmental Awareness: Keep a safe distance from obstacles, dangers, and divers.

3. Safety Checks After Operation

- ☐ Power Down: Turn off the ROV before handling or recovering.
- ☐ Check the component for signs of water intrusion or overheating.
- ☐ Thruster and Moving Parts: Clear the debris and inspect for any damage.
- ☐ To avoid tangling, wind and store the tether.
- ☐ Data Review: Look for issues with the system's performance.
- ☐ Final Integrity Check: Check the electrical and structural elements.
- ☐ Maintenance Documentation: Note any problems and schedule fixes.

4. Procedures for Emergencies

- ☐ Kill Switch: Make it possible for the ROV to shut down quickly.
- ☐ Provide redundancy in the event of a power outage with backup power.
- ☐ Operator Training: Provide emergency recovery operations training to staff.
- ☐ Fire & First Aid: Keep a first aid kit and fire extinguisher close at hand.
- ☐ Wear the proper protective gear.
- ☐ Checks in case of leakage
- ☐ Members pull the ROV out of the water
- ☐ Co-pilot turns off the power supply
- ☐ wipe off the water on the ROV
- ☐ inspect to determine source of leak
- ☐ check all systems for damage
- ☐ Checks in case of communication loss
- ☐ Co-pilot checks tether and laptop connections
- ☐ Pilot reset the connections
- ☐ Co-pilot cycles the power supply
- ☐ Co-pilot turns the power supply off
- ☐ Members pull the ROV to surfa

9.2 Appendix B: SID

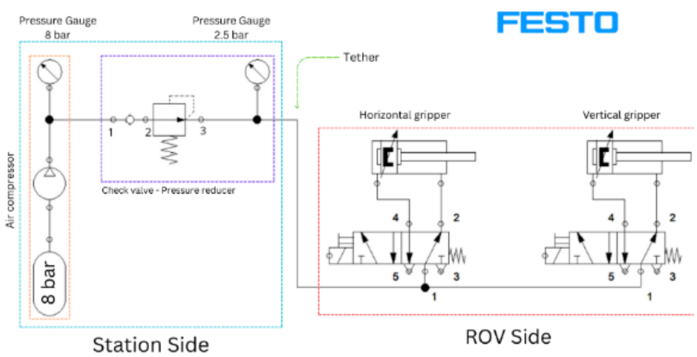
Tether Management protocol

1. A team member at the station is tasked as the tether handler.
2. Tether handler takes the tether from storage bin and uncoils only that much which is sufficient for the job on deck. This will avoid the tether from kinking or tangling.
3. Tether is connected to the surface station strain relief, then ethernet, then power, then pneumatics with outlet valve closed.
4. Strain relief is checked on both ROV and surface station side.
5. While the ROV is in use, the tether handler must constantly hold the tether.
6. Do not pull on the tether to avoid tangling.
7. Never walk over the tether, which could build dangerous pressure spikes in pneumatic lines.
8. ROV pilot must avoid tight rotations around obstacles when possible, to avoid entanglement.
9. Once operations are completed, the tether handler is in charge of disconnecting the tether from the surface station and power, closing the outlet valve before detaching pneumatics.
10. After the disconnection, the tether handler wraps the tether.

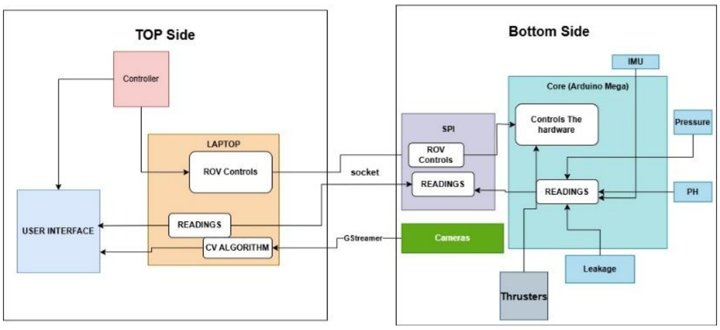
Table 8: Tether Management protocol.

9.3 Appendix C: SIDs

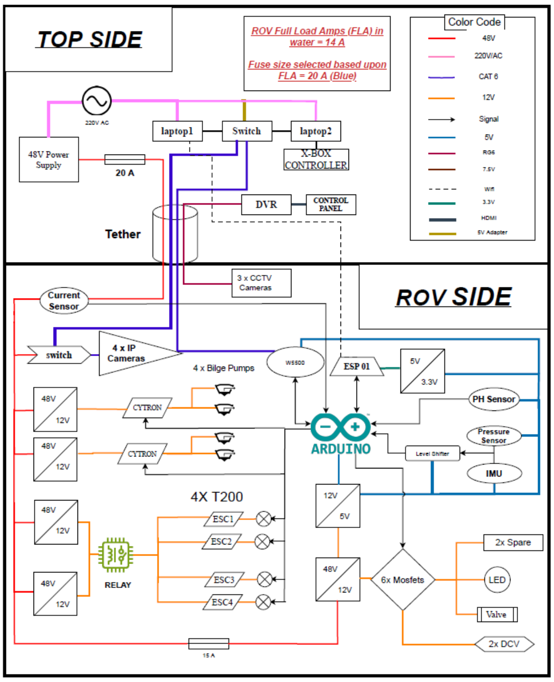
Pneumatic SID



Software SID



Electrical SID



Float SID