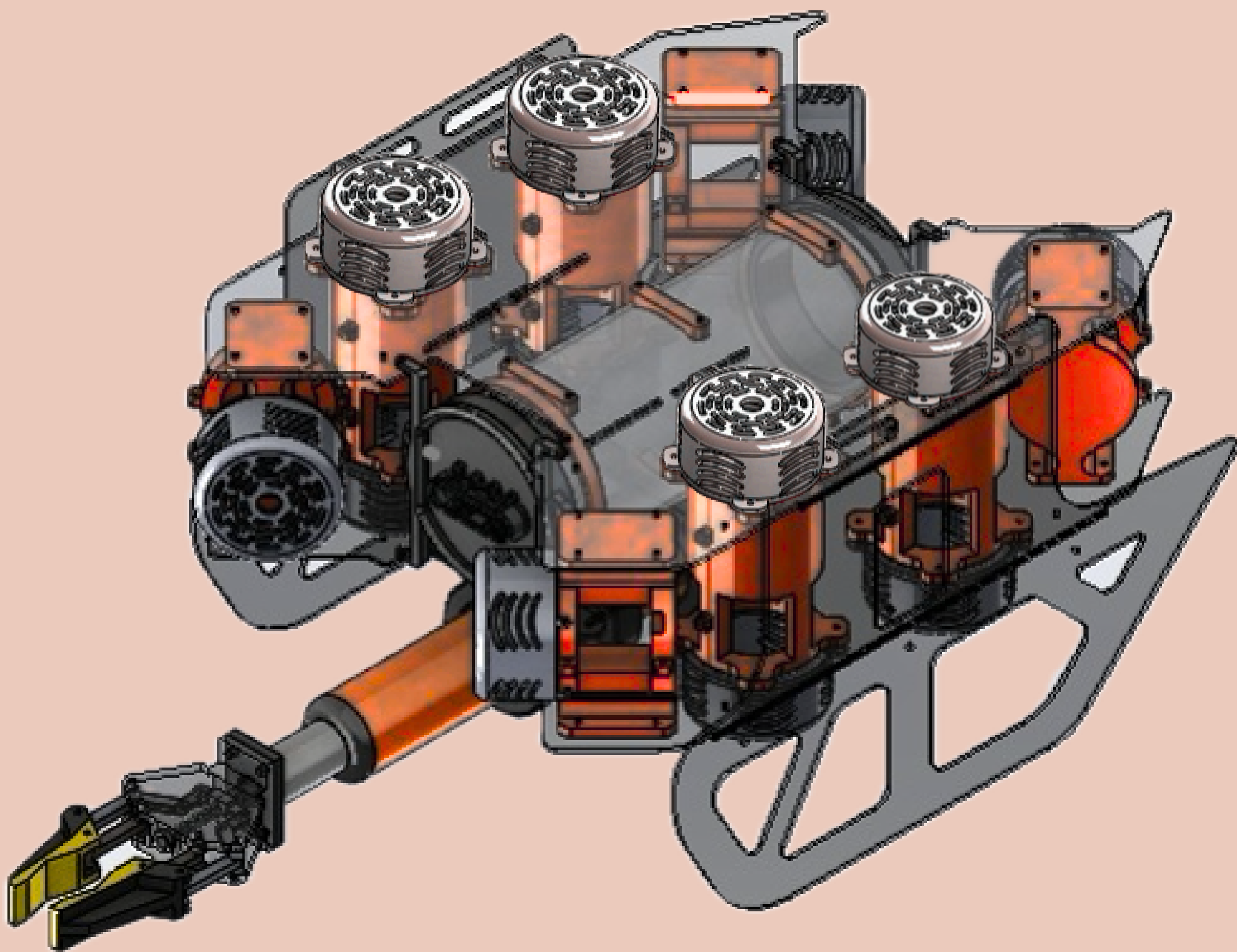




Nova

ASWAN, EGYPT Technical Documentation 2026



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ABSTRACT

NOVA, comprising **18 members**, representing the Arab Academy for Science, Technology, and Maritime Transport (AASTMT) – South Valley Campus in Aswan, **Established in 2026**. This is an undergraduate student team that designs, builds, and competes in the MATE ROV Competition. As first-time participants, we are excited to present our debut remotely operated vehicle (ROV), **Nemo**, engineered to complete the challenging subsea tasks outlined in the MATE Request for Proposals (RFP). Built on the principles of engineering logic and cost-effective innovation, Nemo is designed to be reliable, resourcefully integrated, and competitive. This technical report provides a comprehensive overview of the development and design of Nemo, including our foundational research, technical features, budget optimization, and the synergistic teamwork that brought our inaugural ROV to life.

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DESIGN RATIONAL

Design Evolution

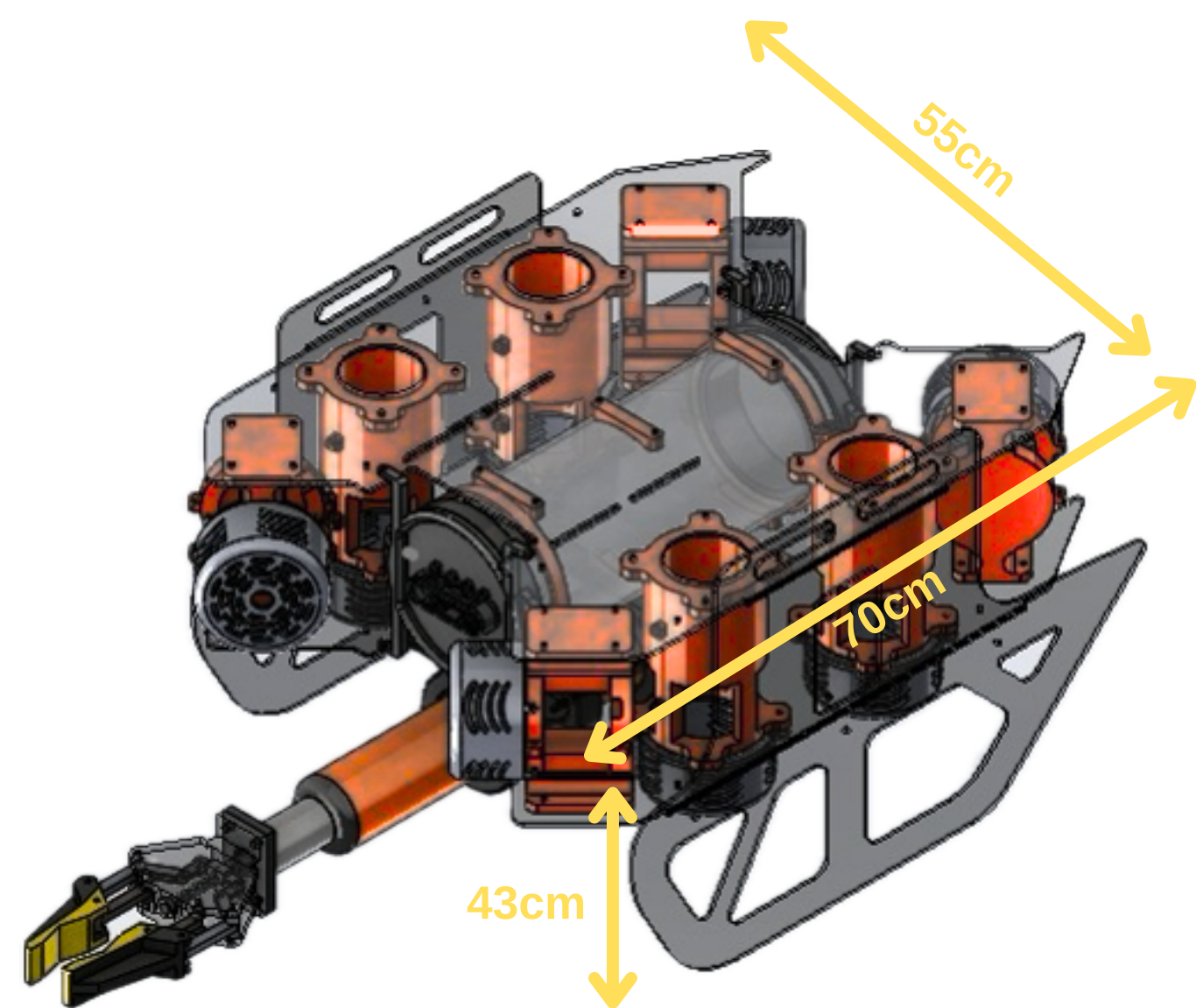
I.Mechanical Design

Design Overview

For the MATE ROV competition, Team NOVA proudly introduces **Nemo**, a highly compact, agile, and modular subsea intervention vehicle. Engineered to operate efficiently within confined underwater environments, Nemo maintains a streamlined hydrodynamic footprint with overall **dimensions of 70x55x43 cm** and an optimized dry **weight of 17.84 kg**.

Frame Architecture

Hydrodynamic Efficiency and Drag Reduction: The open-frame design, combined with the strategic CNC cutouts across the primary side panels, drastically minimizes the vehicle's cross-sectional area. This allows water to flow freely through the chassis, significantly reducing cross-current drag and ensuring that thrust energy is converted directly into propulsion rather than fighting water resistance.



ROV's Dimentions

Material selection

By combining this optimized structural shape with a centralized mass distribution, Nemo provides a rigid, highly stable platform capable of executing delicate spatial metrology and heavy-lifting tasks with zero structural flex.

Cladding: Instead of utilizing traditional solid aluminum or pure acrylic for the main structural plates, our team innovated by manufacturing the frame from CNC-routed Cladding (a composite sandwich panel consisting of **two aluminum sheets** bonded to a **polyethylene** core). This strategic material choice offers an exceptional **strength-to-weight ratio**; it provides the rigid, **unyielding characteristics of metal** to prevent frame flexing under heavy payload operations, while the polymer core drastically reduces the vehicle's overall mass and inertia.

PETG: For complex geometric components such as thruster mounts, camera brackets, and bumpers, we utilized **Polyethylene Terephthalate Glycol (PETG)** 3D printed at an optimized **15% infill density**. Rather than relying on heavy 100% infill, our team maximized the strength-to-weight ratio by combining this lightweight internal gyroid structure with increased outer perimeter wall thickness. This strategic manufacturing choice drastically reduces the ROV's overall mass and in-house printing time.

Material	Cost	In-House Fabrication?	Corrosion Resistance	Density [g/cm³]	Mechanical Properties	Application in NEMO
Cladding (ACP)	\$	Yes (CNC Router)	Excellent	~ 1.35	High Rigidity, Low Weight	Main Open-Frame Chassis
Solid Aluminum	\$\$	Yes (CNC Mill)	Medium (Pits)	2.70	Very High Yield Strength	Endcap Flanges (Anti-deformation)
PVC	\$	Yes (Lathe / Saw)	Excellent	1.38	High Compressive Strength	Main Electronics Housing
Acrylic	\$	Yes (Laser Cutter)	Excellent	1.18	Optically Clear, Brittle	Camera & Stereo Viewports
PETG	\$	Yes (3D Printer)	Excellent	1.27	High Impact Absorption	Thruster Mounts & Nozzles
Stainless Steel	\$\$\$	No	Excellent	8.00	Extremely High Strength	Rejected (Too heavy, hard to machine)

Quantitative trade-off analysis of potential structural materials.

DESIGN RATIONAL

Mechanical System

I. Propulsion System:

The propulsion system for Nemo was engineered by Nova Team to achieve a full Six Degrees of Freedom (**6-DOF**). This high performance array is essential for navigating the complex underwater environments defined in the MATE RFP, allowing for precise lateral translation and the high angular stability required during heavy-payload retrieval. Nemo implements an **8-thruster** array distributed as follows.

The team selected **2000 GPH Bilge Pumps** as the core of Nemo's propulsion. While traditionally used for water evacuation, these units were repurposed as thrusters due to their high thrust-to-weight ratio and cost-efficiency.

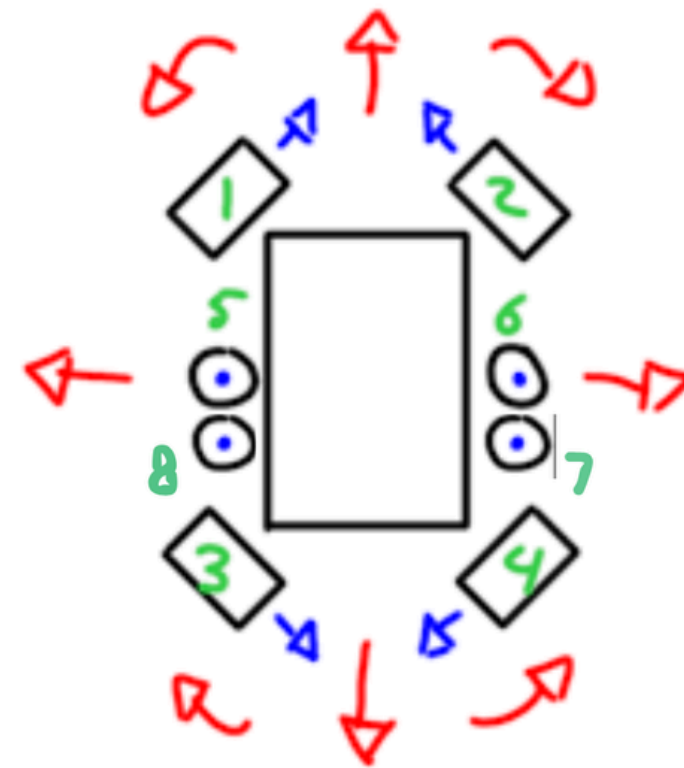
To transform these into high-performance underwater thrusters, Nova Team implemented several key modifications:

Thruster's Configuration

Nemo's 8 motors are strategically placed to maximize control authority across all axes of the movement:

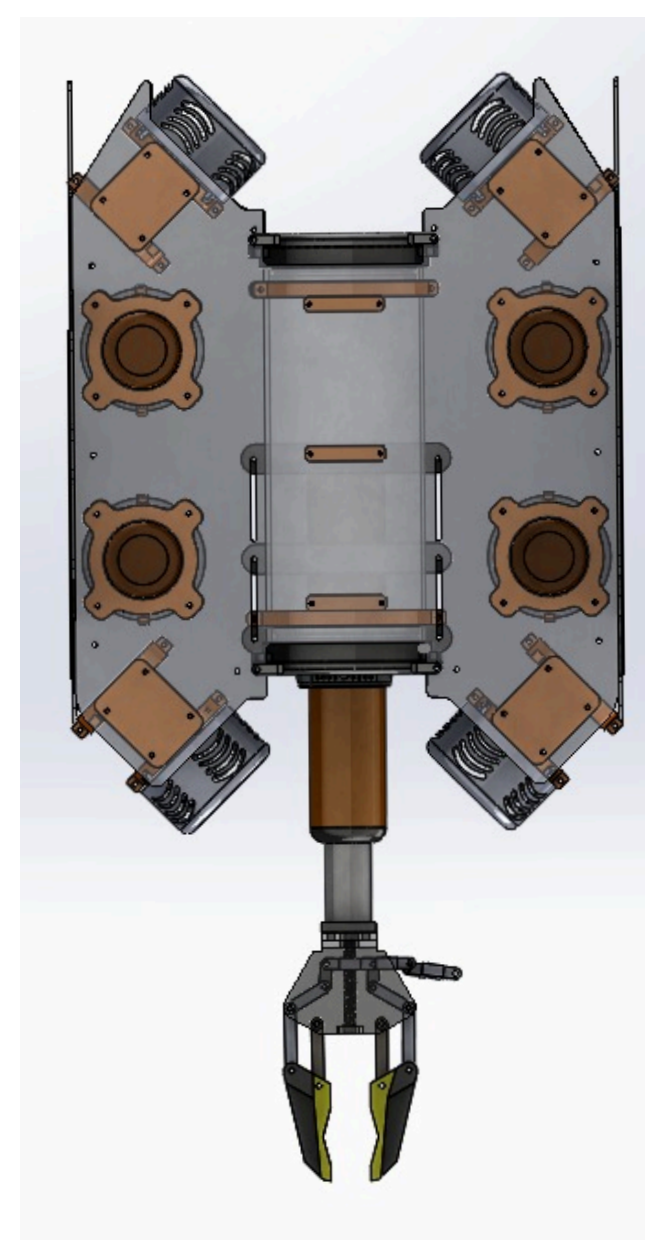
Vectored Horizontal Array (4 Thrusters): Mounted at 45-degree angles (X-pattern) at the frame corners. This vectored geometry allows Nemo to perform Surge (forward/back), Sway (side-to-side/strafing), and Yaw (precise rotation) maneuvers simultaneously.

Corner-Stabilized Vertical Array (4 Thrusters): Positioned at the extreme corners of the frame. This wide-base "Heavy-Vertical" bias facilitates rapid Heave (ascent/descent) and provides maximum leverage for controlling Pitch and Roll, ensuring Nemo remains level even when lifting heavy objects.



Performance and Force Analysis

Based on experimental data from our modified 2000 GPH bilge pump thrusters, each unit produces approximately 3kilograms of thrust under 12V operation. With eight thrusters integrated into Nemo's architecture, the vehicle achieves an estimated total thrust capacity of approximately **24 kilograms**. This provides the necessary force for rapid maneuverability, active stabilization against currents, and the high-torque required for payload manipulation during mission operations.



Thrusters Positions

DESIGN RATIONAL

Mechanical System

Propeller and Nozzle Design

High-Efficiency 3-Blade Propellers: We replaced the original impellers with three-blade propellers to achieve an optimal balance between high thrust and reduced cavitation, allowing Nemo to move more water with less motor strain.

Hydrodynamic Kort Nozzles: Each thruster is encased in a custom-designed nozzle. These function as Kort nozzles, accelerating water flow and increasing total effective thrust.

Safety Integration & Material Integrity: Each thruster is fitted with custom IP2X motor safety shrouds manufactured from 3D-printed PETG.



3 Plades Propeller

Bouyancy

To eliminate trial-and-error, Nemo's buoyancy was mathematically pre-determined. Using SolidWorks and Archimedes' Principle, we quantified displacement vs. mass before assembly. High-density closed-cell foam was used for hydrostatic resistance and zero water absorption at depth. Placing this foam high and ballast low maximized the distance between the Center of Buoyancy (**CoB**) and Center of Gravity (**CoG**). This creates a passive restoring torque (pendulum effect) that self-levels the ROV, eliminating the need for active thruster compensation for pitch and roll and conserving battery life. This baseline allows for rapid pool-side balancing of varying payloads.

II Cameras housing

Navigation Cameras

To protect the Raspberry Pi and USB cameras, we designed highly compact, custom housings. The main body of each housing is 3D-printed from impact-resistant PETG. The front viewport is made from optically clear Acrylic, which was precision-cut using a CNC machine. This specific manufacturing method ensures perfectly flat, micro-crack-free edges for a reliable watertight seal. The final assembly is permanently sealed and reinforced using high-grade marine epoxy sealant. This chemically bonds the acrylic viewport to the PETG frame, creating a rigid, and completely watertight barrier. This robust design allows quick repositioning along the frame for optimal visibility, without compromising the main seal.

Stereo Camera Housing

To protect our Intel RealSense camera for vision, we engineered a custom enclosure featuring a 3D-printed high-impact PETG body paired with an optically clear Acrylic viewport. Processed via CNC laser cutting, the acrylic achieves a flame-polished edge that eliminates structural micro-cracks under deep-water hydrostatic loads. Rejecting permanent silicone adhesives, the viewport bolts directly to the PETG body to evenly compress a custom face-seal O-ring, ensuring a flawless, reusable mechanical seal. Furthermore, the meticulously reverse-engineered internal geometry accommodates the bulky native USB connector without wire splicing. This critical design preserves factory shielding, preventing high-speed data loss during autonomous target recognition.



Stereo Camera Housing

DESIGN RATIONAL

Mechanical System

III Electronics Housing

At the heart of Nemo is a sealed pressure housing designed to protect all critical electronic components. This enclosure ensures that the control systems and power electronics remain in a stable, dry environment throughout the mission.

Specifications and Construction

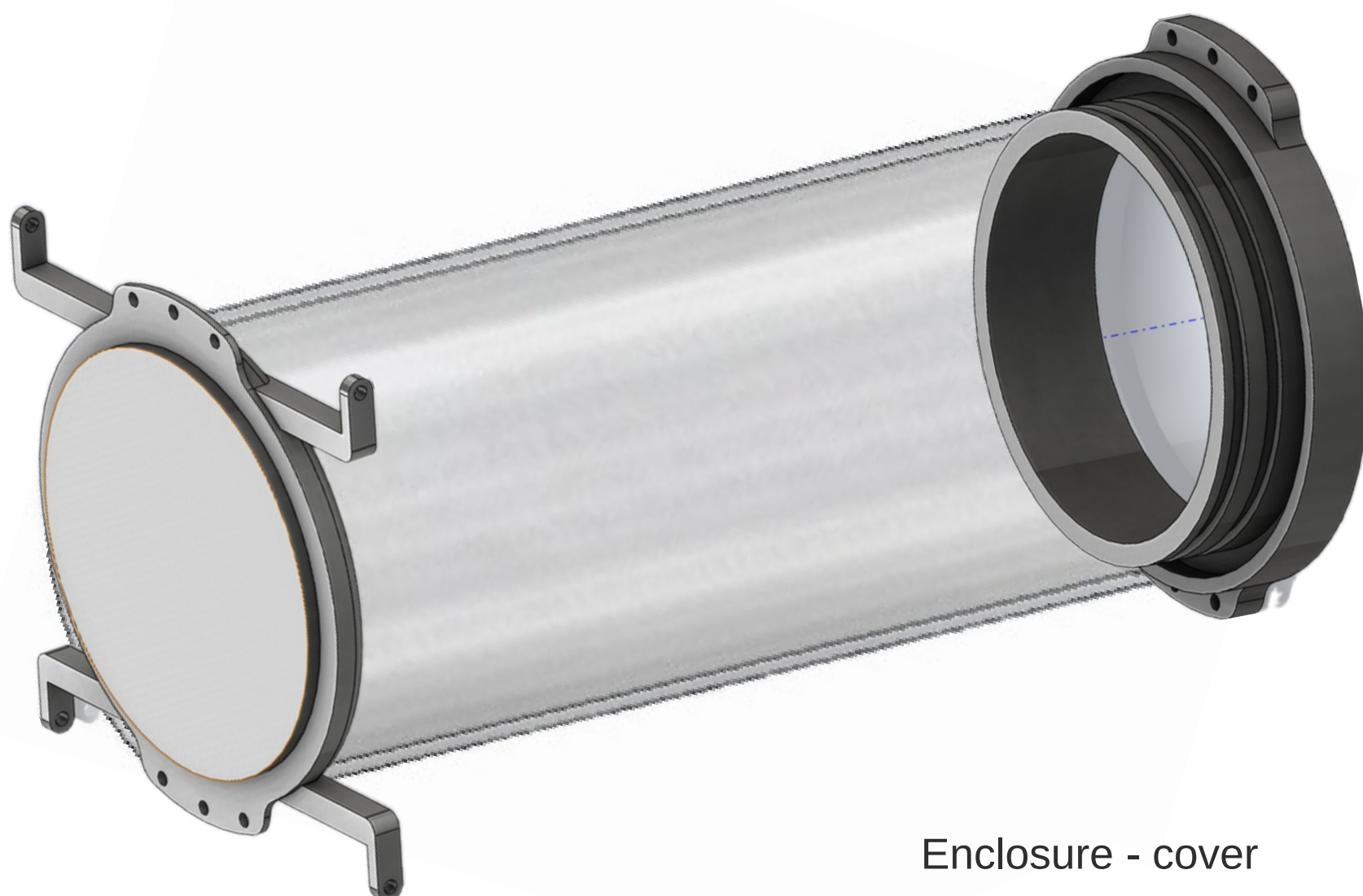
The housing consists of a custom-built PVC cylindrical enclosure measuring 15cm in diameter and 40cm in length. This volume provides sufficient internal space to accommodate the Raspberry Pi, motor drivers, and power regulation components while maintaining an organized internal layout.

PVC was selected as the primary structural material due to its high strength-to-weight ratio, corrosion resistance, cost efficiency. Compared to metal housings, and natural resistance to saltwater degradation, providing a robust primary barrier.

Flange Design and Assembly

To ensure a secure mechanical interface between the cylindrical body and its end caps, custom-machined Aluminum Flanges were integrated into the housing system.

To ensure absolute sealing integrity at both ends of this hull, we engineered custom CNC-machined Anodized Aluminum Flanges (Endcaps). The extreme structural rigidity of solid metal was a deliberate choice; unlike plastics, aluminum completely eliminates the risk of micro-deformation or flexing under deep-water pressure. This rigidity is crucial, as it ensures the primary sealing mechanism—radial Buna-N/NBR O-rings seated in precision-machined grooves—remains perfectly compressed at all times. This creates a flawless, reusable mechanical seal without the need for messy, permanent silicon adhesives. Furthermore, the anodized surface treatment on the flanges acts as a critical protective barrier, completely mitigating the risk of galvanic corrosion when exposed to the harsh subsea environment.



Enclosure - cover



DESIGN RATIONAL

Mechanical System

IV. Tether Design

Tether Composition and Protection

The tether is Nemo's connection to the surface control station. It provides power, communication, and recovery capability.

As the critical lifeline of the ROV, flexibility, low weight, and signal integrity were the primary goals for our custom-built umbilical. Rather than relying on expensive commercial solutions, our team engineered this tether from the ground up to optimize the budget while meeting the exact specifications of our high-load mining operations. The entire assembly is encased in an abrasion-resistant jacket, maintaining a highly compact 13mm Outer Diameter (OD). To guarantee reliable power delivery over the 20-meter operational length, we utilize two 4mm² (10 AWG) copper conductors for the 48V system. Given our peak system draw of approximately 30A, this ensures minimal voltage drop and prevents system brownouts. Crucially, these power conductors directly contact the outer jacket, allowing the pool water to act as a passive heat sink to dissipate internal heat losses. Data telemetry is maintained via an 8-core shielded Cat6 Ethernet cable, completely isolated from electromagnetic interference (EMI). Because physical strain is a major point of failure, internal tether voids are packed with Aramid (Kevlar) fibers anchored directly to the ROV's structural frame. This strain relief mechanism isolates the internal copper from extraneous tension. Furthermore, these Kevlar members are integrated with Super Absorbent Polymer (SAP) yarns that instantly swell into a watertight gel if the jacket is ever punctured



Strain

Tether Management Protocol

A designated Tether Manager follows this workflow to ensure the safety of Nemo and all team members:

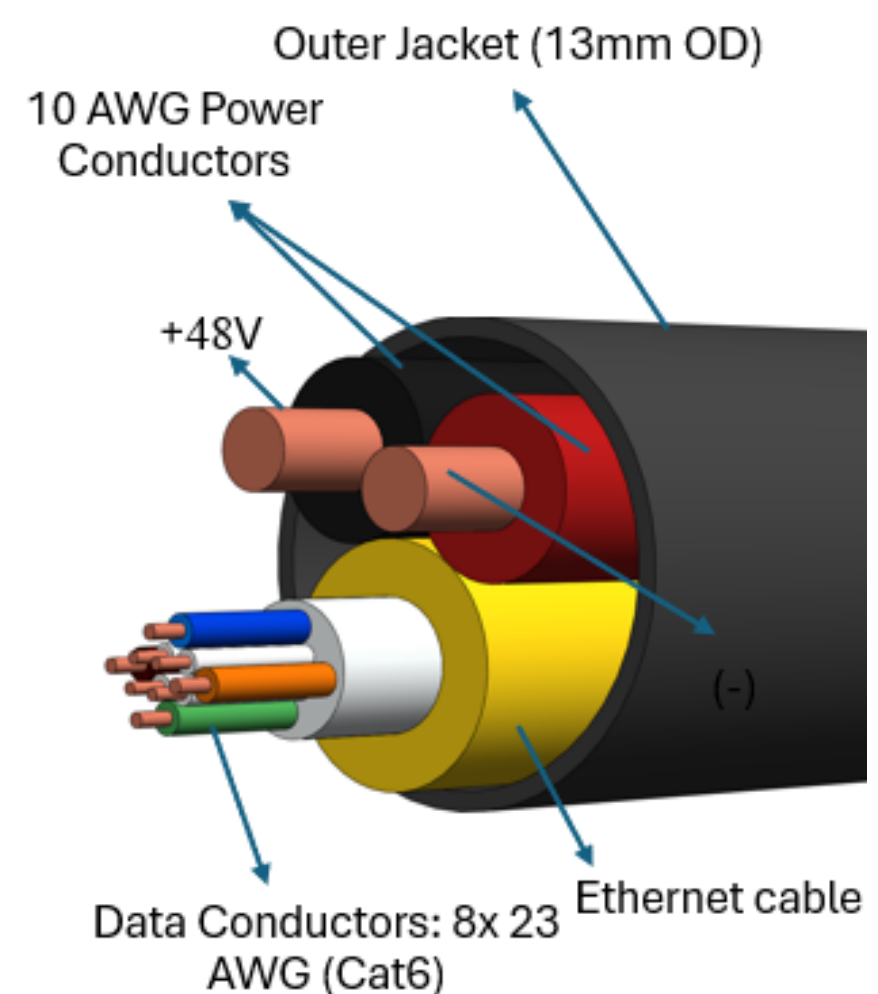
1.Pre-Mission Prep: A designated tender uncoils the tether in a "figure-eight" pattern on the deck to prevent internal wire fatigue, kinking, or tangling.

2.Sequential Connection: Connections to the surface station are made sequentially—data first, then power—and the mechanical strain relief is physically verified on both the ROV and surface station.

3.Active Deployment: During operations, the tender feeds slack precisely in sync with ROV movement. Excessive slack is actively avoided to prevent propeller entanglement or snagging on pool obstacles.

4.Pilot Communication: The ROV pilot communicates continuously with the tender to avoid consecutive 360-degree rotations that could induce torsion in the cable.

5.Post-Mission Retrieval: Operations conclude by immediately disconnecting power via the emergency inline breaker, followed by the data link. The tether is wiped down and recoiled using the figure-eight method for safe storage.



Tether cross section

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Hardware System

I. Hardware System Architecture

The electrical architecture of the NOVA ROV is designed around three core principles: modularity, fault tolerance, and signal isolation. To manage the robust payload and execute complex subsea interventions, the system adopts a decentralized processing approach. High-level computations and vision processing are handled by a microcomputer, while real-time hardware actuation is offloaded to a dedicated microcontroller. All power and signal lines are strictly isolated to prevent electromagnetic interference (EMI) from the high-current propulsion system.

II. Control and Processing Units

Inside the ROV, the control system is built around two main units: the Raspberry Pi 4 and the Arduino Mega. Each of these components has a clearly defined role, and together they form a layered control architecture.

Raspberry Pi 4B: functions as the central processing and communication hub. It receives commands from the laptop via the Ethernet cable and is responsible for handling high-level operations such as data processing and video streaming.

Arduino Mega 2560: functions as the hardware interface layer, managing low-level control and time-critical actuation. It generates precise Pulse Width Modulation (PWM) and digital directional (DIR) signals for all onboard hardware

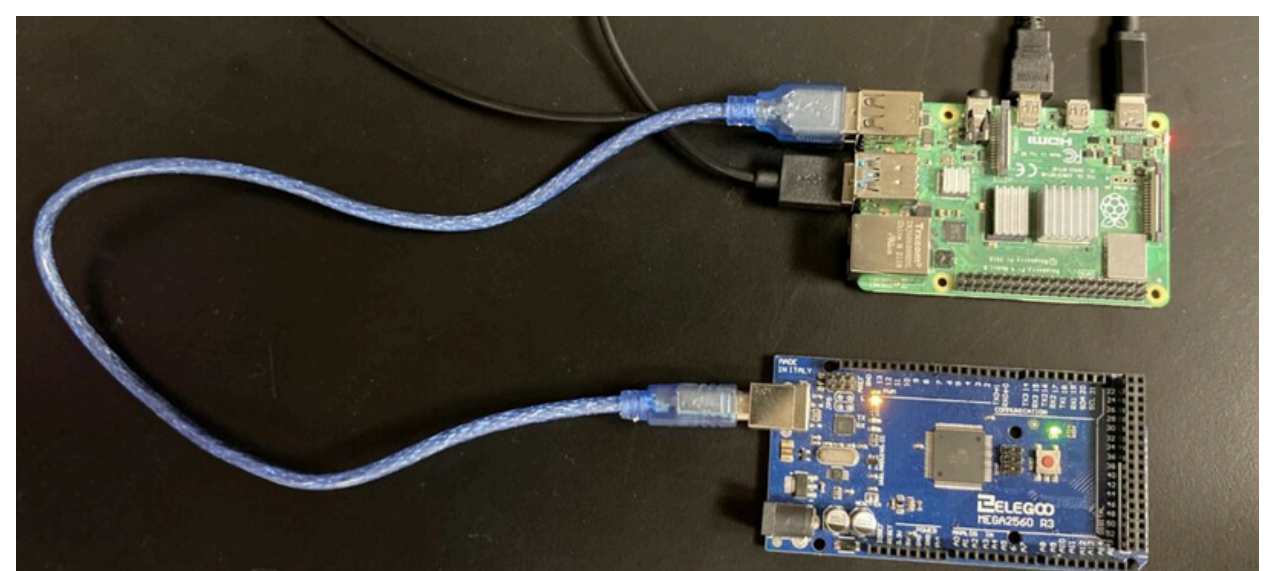
Communication between the Raspberry Pi and Arduino is established through a wired connection, allowing commands to flow from the Raspberry Pi to the Arduino, and sensor data to be sent back.

III. Power Conversion and Distribution

To distribute power effectively, the system uses multiple stages of voltage conversion. The 48V output is stepped down using three DC-DC converters, each rated at 48V to 12V and 30A. The outputs of these converters are connected in parallel to provide a stable 12V supply with a combined current capacity of up to 90A. These converters share the load, preventing overheating and improving reliability. The 12V output is then distributed to the motor drivers, which require a stable voltage to operate the thrusters efficiently.

In addition to this, a secondary conversion stage is used to step down 12V to 5V. This is necessary because the Raspberry Pi operates at 5V and cannot tolerate higher voltages. By isolating this conversion stage, the system ensures that sensitive electronics are protected from voltage fluctuations caused by high-power components.

Furthermore, the system's overcurrent protection is calculated based on the Configured (Nominal) Power rather than the absolute theoretical maximum. This is a deliberate engineering choice, as the probability of all eight thrusters and auxiliary components operating at **100 stall current** simultaneously is practically zero. Designing the top-side fuse around the nominal load provides a faster, more accurate fault response during actual subsea missions.



Processing Units

DESIGN RATIONAL

Hardware System

IV. Motor Control Mechanism

To achieve high maneuverability and overcome hydrodynamic drag, the propulsion system consists of 8 high-torque 12V Bilge Pumps configured to provide full 6-Degree-of-Freedom (6-DOF) movement.

Motor Drivers: To control all eight thrusters efficiently, 4 Cytron SmartDrive dual-channel motor controllers are used. Each motor driver is connected to two thrusters, allowing centralized control while maintaining balanced electrical loading. These drivers were specifically selected for their high continuous current capacity and reliable solid-state switching.

Signal Isolation: Each Cytron driver is commanded via PWM and DIR signals from the Arduino. To ensure stable operation, the logic ground of the motor drivers is unified with the Arduino, while the high-current 12V rails are kept completely isolated from the logic circuitry to protect the Arduino from damage and ensure reliable operation.



Cytron Motor Driver

V. Internal Connections

To eliminate overcrowded wiring and prone-to-failure screw terminals, our main enclosure utilizes WAGO connectors. Their spring-pressure technology creates a vibration-proof hub that prevents accidental disconnections. For the primary 48V/30A tether input, we strategically selected a polarized XT60 connector; operating at only 50% of its rated capacity provides a critical thermal safety margin inside the sealed hull, while inherently preventing reverse polarity. To reinforce vulnerable connection points and ensure robust electrical insulation, all soldered wire joints are fully sealed with adhesive-lined heat shrink tubing, preventing any risk of short circuits. This modular approach creates a highly organized, secure hub for rapid field swaps. Furthermore, to preserve absolute signal integrity, high-current pathways are physically isolated from sensitive data lines.



XT60

DESIGN RATIONAL

Payloads and Tools

I. Sensors

To ensure the cleanest possible data for autonomous filtering, NOVA's sensors are strategically isolated from high-current propulsion noise. The MPU-9250 IMU is mounted at the ROV's Center of Gravity (CoG) to eliminate offset-induced lever-arm errors, providing precise angular velocity and orientation. Externally, the MS5837 Pressure Sensor is positioned away from thruster wash to prevent localized pressure spikes from skewing depth telemetry. Both sensors communicate via I2C protocol using shielded twisted-pair cabling to neutralize Electromagnetic Interference (EMI). For maximum stability, the entire suite is powered by an Isolated 5V Logic Rail, protecting delicate hardware from voltage transients during motor reversals.



Blue Robotics Pressure Sensor (MS5837)

II. High-Intensity Illumination

To combat the light absorption and turbidity inherent in deep-water environments, the ROV is equipped with dual CREE U1 LED Spotlights. These units are critical for maintaining the high-fidelity visual data required for 3D modeling and navigation.

Backscatter Mitigation: The spotlights are strategically offset from the primary camera axis to minimize "backscatter"—the reflection of light off suspended particles—ensuring a clear "Signal-to-Noise" ratio for the HDR camera nodes.

Thermal Management: Encased in rugged metal shells, these lights utilize the surrounding water as a passive heat sink. This prevents thermal throttling and ensures consistent luminous flux during high-duration inspection tasks.

Control: The lighting array is managed through the NOVA power distribution network, allowing the pilot to toggle illumination via the GUI based on real-time visibility conditions.

III. Cameras

NOVA utilizes a triple-camera system strategically distributed to eliminate operational blind spots.

Intel RealSense Stereo Camera: Mounted at the absolute front, it acts as the primary eye for 3D mapping and forward metrology. It features a dual-purpose feed, providing both standard RGB video for navigation and high-bandwidth depth data for range finding.

Navigation Cameras: To ensure total situational awareness and eliminate operational blind spots, the ROV utilizes a distributed network of high-speed navigation nodes. Centrally positioned at the chassis base, a USB Camera provides a wide-angle view of the seabed and lower footprint, which is essential for monitoring payload drops and maintaining ground clearance. This is complemented by a Pi-Cam mounted to provide a first-person perspective of the manipulator; its modular design allows for rapid reconfiguration to monitor gripper-object interactions or serve as a dedicated aft-view feed. Together, these nodes deliver ultra-low latency telemetry, providing the pilot with the precise visual feedback required for complex subsea maneuvering.



Intel RealSense Camera



CREE U1 LED

DESIGN RATIONAL

Payloads and Tools

IV. Manipulator Design

To perform retrieval and heavy-lifting tasks in the competition, the team designed a custom 2-DOF (Degree of Freedom) parallel gripper. The design focuses on high mechanical advantage, compact size, and reliable operation underwater, allowing the manipulator to apply strong gripping forces while operating in subsea environments.

Mechanical Configuration

The manipulator uses a lead-screw driven mechanism to generate high clamping force while keeping the system compact and efficient.

DOF 1 – High-Torque Clamping

The gripping action is produced by a high-torque DC motor connected to a power screw (lead screw) and nut assembly. When the motor rotates the screw, the nut moves linearly along the screw. This linear motion drives a parallel linkage mechanism that opens and closes the gripper jaws.

The lead-screw system provides high mechanical advantage, allowing the gripper to generate strong clamping forces. Another important property is that the mechanism is self-locking, meaning the jaws remain closed and hold the object securely even when power to the motor is removed.

DOF 2 – Wrist Rotation

The entire gripper assembly is mounted on a precision servo motor, which provides rotational movement. This second degree of freedom allows the operator to rotate and align the gripper with objects underwater without needing to reposition the entire ROV. As a result, the manipulator can approach targets from different angles and perform more precise retrieval operations.

Gripper Mechanism

Nemo is equipped with a gripper that allows it to interact with objects underwater. The gripper is controlled by the Arduino Mega, which sends control signals to open and close it. However, due to the high current requirements of the gripper, it cannot be driven directly by the Arduino. To solve this issue, an external driver or control board is required.

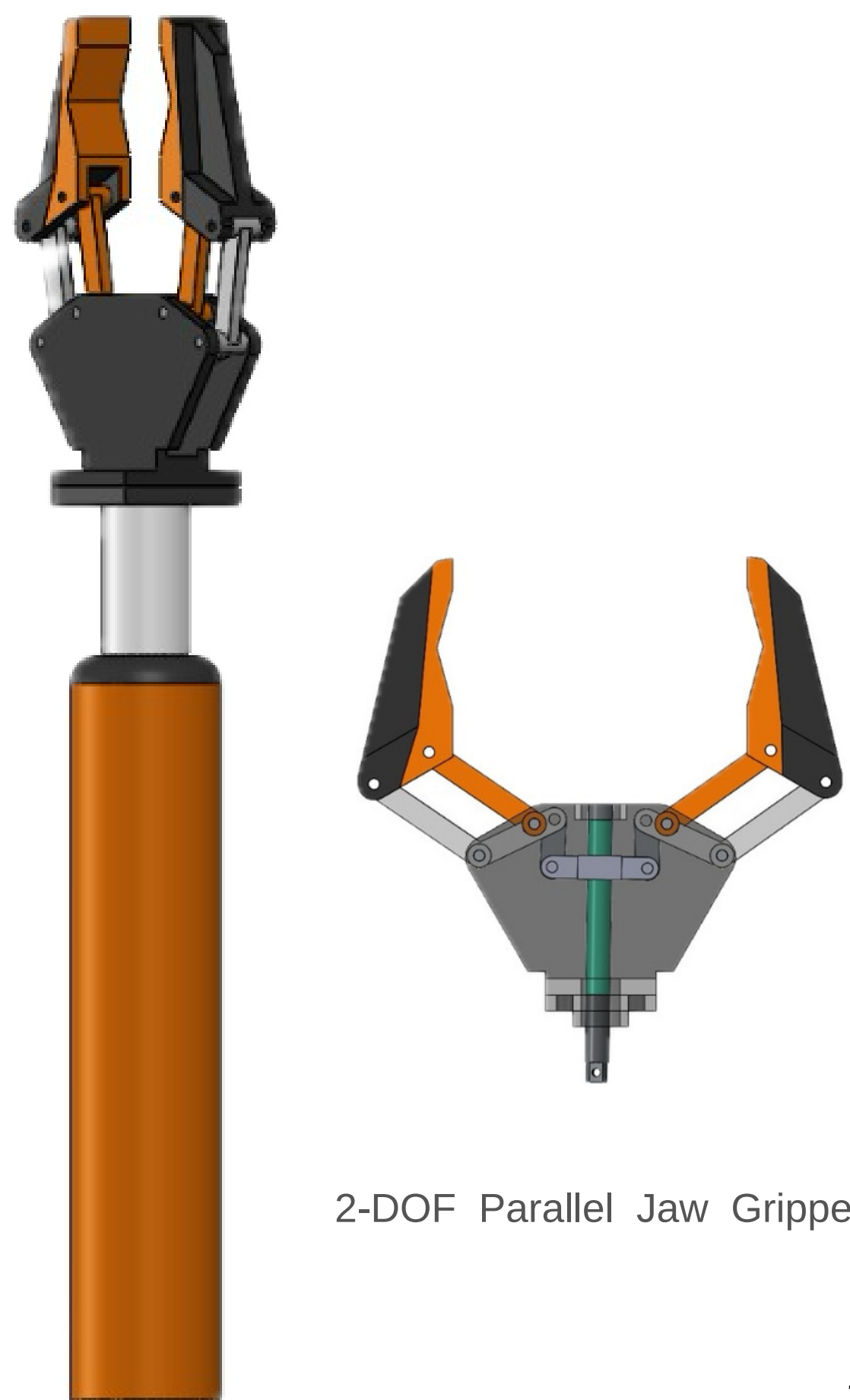
This additional hardware handles the power demands of the gripper while the Arduino provides only the control signals. This approach protects the Arduino from damage and ensures reliable operation.

Grip Surface

To improve gripping reliability, the inner surfaces of the jaws are covered with a high-friction rubber layer. This material increases friction between the gripper and objects such as PVC pipes, tools, or sensor housings, preventing slipping during lifting or manipulation.

Waterproofing Method

To protect the motors from water intrusion, both the DC motor and the servo motor are sealed using epoxy encapsulation (potting). This process fully surrounds the motors with epoxy resin, creating a pressure-resistant and watertight barrier that prevents saltwater from reaching the electrical components.



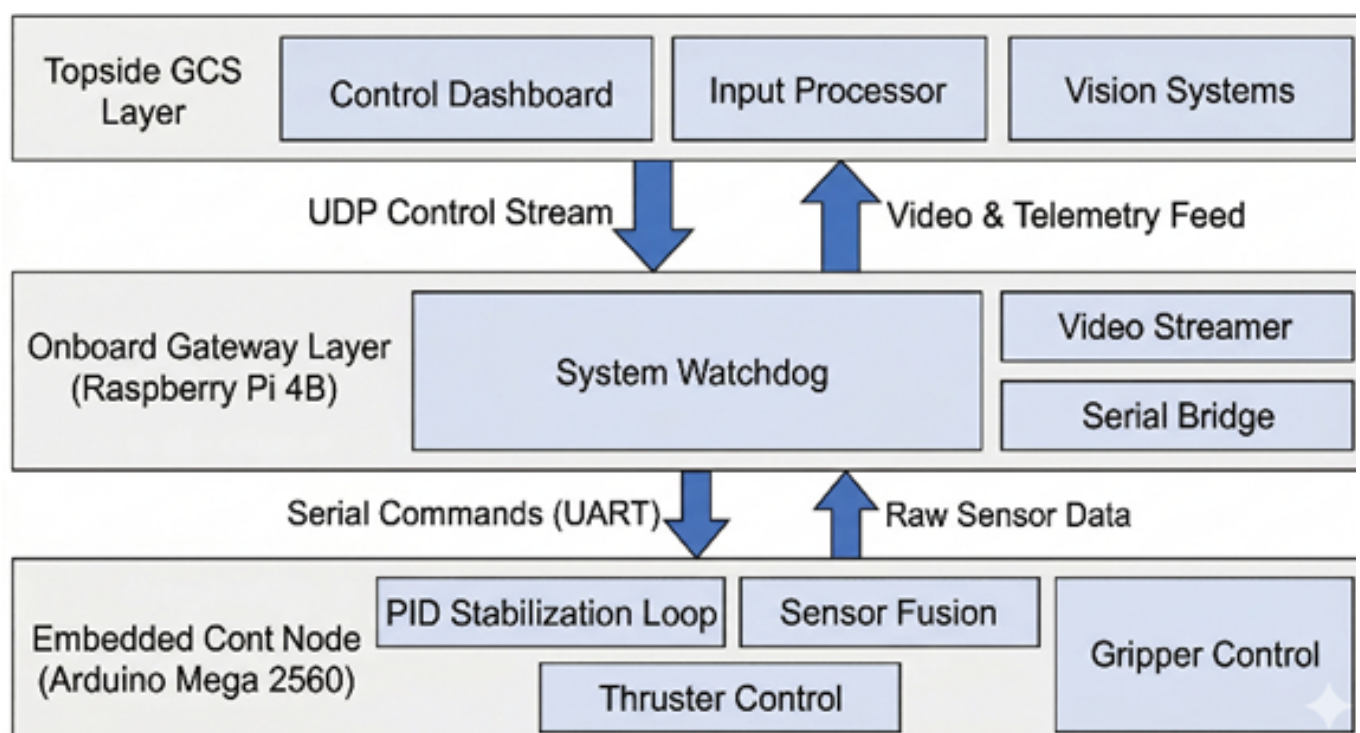
2-DOF Parallel Jaw Gripper

DESIGN RATIONAL

Software System

I. Architectural Overview

The ROV is driven by **NOVA.CO**, a proprietary, full-stack software ecosystem designed entirely by our team for low-latency underwater navigation and real-time data analysis. Built upon a robust and diverse technology stack, this customized environment handles deterministic motor control, video processing, and sensor fusion into a single cohesive network. The hierarchical breakdown, hardware-software interfacing, and exact data flow of this ecosystem are comprehensively illustrated in the architecture diagram below.



Following the illustrated framework, NOVA.CO's operations are distributed across three hierarchical execution layers to completely eliminate processing bottlenecks:

Topside Surface Layer (GCS): This layer acts as the orchestrator, where the Control Dashboard handles computational-heavy tasks like the Vision Systems and processes joystick inputs through the Input Processor. Commands are then transmitted subsea via a low-latency UDP Control Stream.

Subsea Onboard Gateway Layer (Raspberry Pi): Functioning as a high-bandwidth router, the Pi utilizes a robust System Watchdog (for Fail-safe operations) and manages the Video Streamer for real-time video encoding. It employs a Serial Bridge (UART) to deserialize network commands for direct hardware interfacing.

Embedded Control Node Layer (Arduino Mega 2560): To guarantee real-time actuation, all time-critical functions are offloaded to this layer. Operating on a strict 100Hz closed-loop cycle, the Arduino handles Sensor Fusion (IMU/Depth), runs the PID Stabilization Loop, and translates received commands into coordinated PWM Signals for Thruster Control.

II. Control interface

Rather than a single resource-heavy application, NOVA.CO utilizes a **Modular Control Environment** designed for maximum processing efficiency and zero-latency feedback. The pilot manages the ROV through a decentralized, terminal-based architecture that prioritizes raw performance over graphical overhead. Situational awareness is maintained through independent, hardware-accelerated video windows—including the Main **Navigation Feed** (Raspberry Pi Cam and a USB Feed)—both launched via optimized scripts to ensure a delay of <150ms. For complex mining operations, a dedicated **Stereo-Vision Dashboard** is utilized to provide high-resolution spatial data and 3D mapping. All critical system health and Sensor Fusion data (IMU/Depth) are monitored via a **Live Terminal Stream**, providing the pilot with unfiltered, real-time telemetry directly from the subsea gateway. This streamlined approach ensures that the onboard processor remains responsive for time-critical navigation and stabilization.

DESIGN RATIONAL

Software System

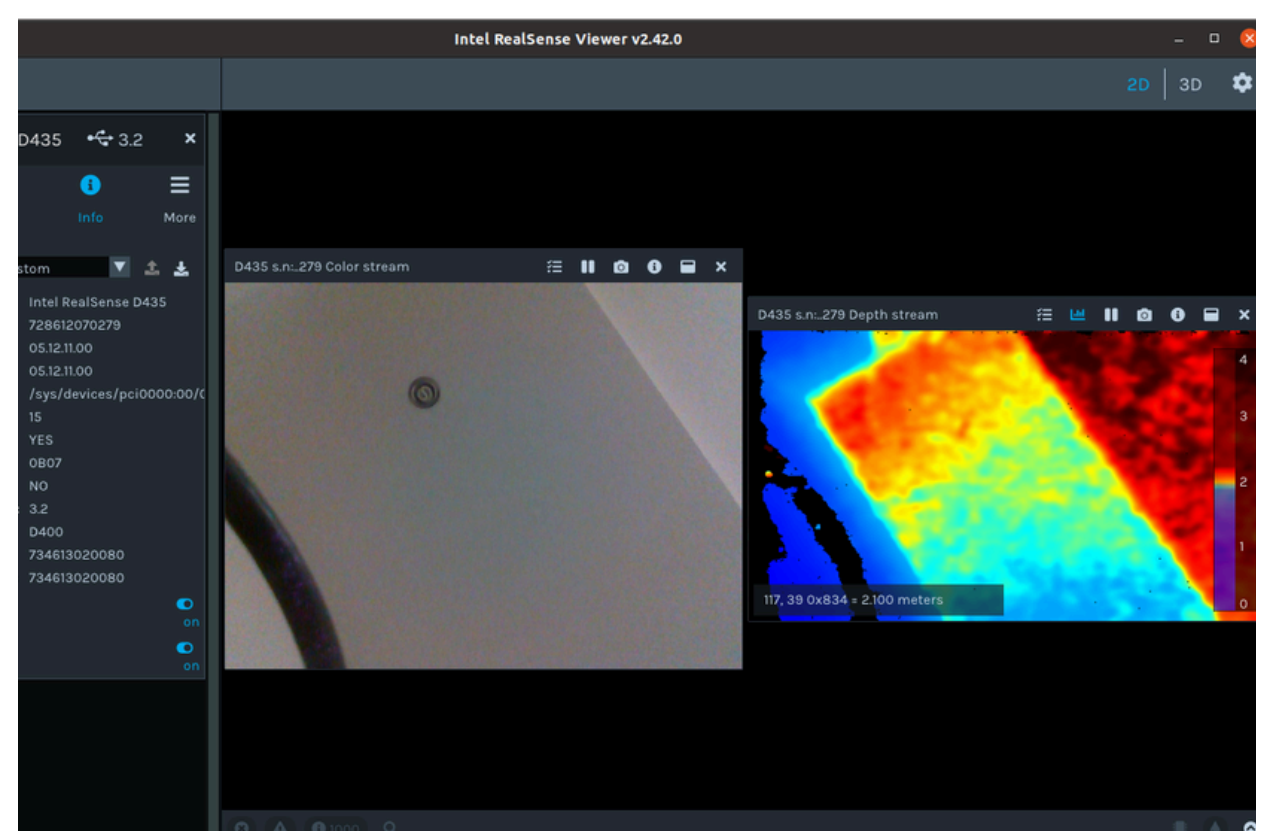
III. Sensor Data Processing

Raw telemetry in subsea environments is inherently chaotic due to electrical noise and hydrodynamic turbulence, prompting our team to develop a rigorous digital filtering pipeline based on extensive field testing. To achieve stable orientation, we implemented a **Kalman Filter** for the **IMU**, an advanced recursive algorithm that predicts the ROV's state to neutralize gyroscopic drift and high-frequency thruster vibrations, maintaining an accurate "Attitude" with an error margin of **<0.5°**. This inertial stability is critical for the ROV's specialized **Depth-Lock task**, where precise vertical positioning is required to interact with mission-specific subsea structures. By applying **Temperature-Compensated** conversions and a **Median-Average Hybrid Filter**, we effectively eliminated the "Depth-Bounce" caused by thruster wash. By calculating the differential against a pre-dive surface baseline, the system achieves a rock-solid **Auto-Depth Hold** with a resolution of **±2mm**, providing the pilot with a precise and vibration-free platform for delicate subsea operations.

IV. Vision System

The ROV's perception architecture is a sophisticated network designed to function as the vehicle's primary spatial intelligence gatherer. At its core, an **Intel RealSense Stereo Camera** provides high-frequency spatial tracking, utilizing its integrated **IMU** to stabilize 3D point clouds during dynamic maneuvers. For pre-mission diagnostics, the hardware is initially interfaced via the dedicated realsense-viewer GUI. Operationally, the specialized Stereo-Vision Dashboard features a split-screen layout, allowing the pilot to view the standard high-definition RGB video during navigation, and then seamlessly switch focus to the real-time Disparity Map and 3D modeling view for complex mining operations.

This enables Non-Invasive Metrology at 90 FPS, instantly computing Euclidean distances to determine the exact range of subsea objects and generate accurate digital twin reconstructions. To ensure total situational awareness, this primary node is supported by two specialized feeds: a High-Dynamic Range (HDR) USB Camera optimized for murky environments, and a Pi-Cam strictly synchronized for gripper operations. To manage these three concurrent high-definition streams, we implemented an Asynchronous Video Pipeline using OpenCV multi-threading. By employing Zero-Copy memory management, video data is routed directly from the network buffer to the display, maintaining a total latency of <150ms. This optimized architecture keeps the CPU load under 45%, ensuring that the high-speed motor control loops remain uninterrupted and responsive.



Intel RealSense viewer

SAFETY

Safety Philosophy

Our safety philosophy is to mitigate risks long before unsafe situations occur. Personnel and equipment safety are highly prioritized throughout the ROV's lifecycle, from manufacturing to deployment. Our team includes a designated safety lead, ensuring that all members learn and comply with strict safety standards set forth by the company and local regulations.

Personnel Safety

Before participating in lab work, all NOVA members receive safety orientation. This orientation introduces members to the correct handling of basic tools, emergency procedures, and the locations of important safety resources such as first aid kits and fire extinguishers. Members are also informed about proper laboratory behavior and required protective equipment, including safety glasses and appropriate footwear.

When using specialized equipment or electrical tools, members must first be trained by a knowledgeable teammate or supervisor. This training ensures that everyone understands how to operate the tools safely and reduces the risk of accidents during construction and testing.



SAFETY

Equipment Safety

A major design element during Nemo's development revolved around preventing injury through vehicle safety features. We addressed both mechanical and electrical hazards cohesively:

Mechanical Protection: To eliminate laceration risks to personnel and prevent damage to sensitive subsea environments, all sharp edges on the Cladding chassis were aggressively filed or covered. Crucially, all propulsion units are enclosed within custom 3D-printed **IP2X-compliant thruster shrouds**. This specific rating guarantees the apertures are too small for human fingers or loose cables to contact the rotating propellers. Furthermore, the tether is protected by a braided sleeve and anchored with **mechanical strain relief** mounts on both the ROV and the surface station, preventing catastrophic tension from reaching the delicate electrical penetrators or pulling control laptops into the pool.

Electrical Protection: To ensure the ROV does not leak during deployment, our standard operating procedure includes conducting a positive-pressure leak test using a **pneumatic Schrader valve** before every mission. All moving external electromechanical components (DC/Servo motors) utilize advanced **epoxy encapsulation (potting)**, ensuring zero exposed electrical connections. Internally, all individual power distribution branches are guarded by fast-acting **inline blade fuses** precisely rated for their specific loads to prevent localized short circuits.

Safety Procedures

To support safe working practices, NOVA has developed clear procedures for assembling, testing, and operating the Nemo ROV. These procedures guide team members through each stage of the project and help maintain consistent safety standards.

Safety guidelines and checklists are available to all team members and are reviewed regularly to ensure that safe practices are followed throughout the project.

Operational Safety

team proactively identifies potential hazards during operation by performing a Jobsite Safety and Environment Analysis (**JSEA**) before any deployment. This mitigates risks by ensuring proper restraint of tools, securing the tether staging area, and removing loose debris.

Additionally, built-in safety questions in the surface station software function as a **digital arming sequence**. The thrusters cannot receive PWM signals until the pilot confirms the ROV is completely submerged and clear of the deck crew, enforcing strict "Hands-On / Hands-Off" protocols.



Shroud

TEAMWORK

Project Management

The ROV project was managed under the framework of a well-organized team structure, ensuring clear responsibilities, efficient collaboration, and systematic progress toward the mission objectives.

Company Overview and Team Philosophy

Our team believes that a successful project starts with unwavering trust and a clear line of communication between all members. By setting realistic short-term goals to keep team members goal-oriented, a master timeline is laid out by experienced team members. We ensure that each member in the company has a specific responsibility that represents his strengths.

For collaboration, we used various tools:

- **WhatsApp** for quick updates.
- **Google Drive** for shared files.
- **Excel** and **Google Sheets** for data organization.
- **Google Meet** and **Zoom** for meetings.
- **SolidWorks** for 3D modeling of the ROV.

Organizational Structure and Schedule

Our team operates under a structured leadership model with a CEO, CTO, and CFO overseeing key areas of operation. We are divided into three main sub-teams: Mechanical, Software, and Electrical. Each sub-team is led by a team leader who manages tasks, progress tracking, and quality control, while coordinating directly with upper management. Additionally, a technical writing director is responsible for managing all documentation and posters to ensure professional standards.

Training and Workshops (Week 1)	The competition manual was reviewed, project objectives were defined, and team roles and responsibilities were assigned.
Research and Development (Week 2)	The team reviewed past designs to find strengths and weaknesses. A final design was chosen, and detailed plans for the systems were made.
Implementation and Fabrication (Weeks 3–5)	Started designing with SolidWorks and selecting electrical components. Fabrication started with building the ROV frame and developing prototypes.
Specialized Development (Weeks 6–7)	System integration involved motors and electrical connections. Specialized subsystems like the Vertical Profiling Float were developed, and the closed-loop control system was refined. Water testing assessed functionality and identified improvement areas.
Documentation and Presentation Planning (Week 8)	The team worked on creating technical documentation. This included engineering reports, posters, and presentation materials to convey the project's results.
Task Strategy and Troubleshooting (Week 8 – Ongoing)	The final phase involved debugging and resolving any remaining technical issues. The team also developed strategies for efficiently completing competition tasks.

TEAMWORK

Project Management

III. Personnel and Roles

Each team member was assigned specific roles to optimize productivity and ensure accountability:

- **Team Leader:** Oversaw the project timeline, coordinated between subsystems, and managed overall progress.
- **Mechanical Lead:** Responsible for designing and fabricating the ROV frame, thrusters, and structural components.
- **Electrical Lead:** Managed the power system, motor connections, sensors, and wiring schematics.
- **Software Lead:** Developed the control algorithms, integrated sensors, and maintained communication protocols.
- **Documentation & Presentation Officer:** Prepared engineering reports, technical drawings, and presentation materials. All members contributed collaboratively to system integration, testing, and problem-solving, ensuring each subsystem functioned harmoniously within the overall design.

ACCOUNTING & FINANCIALS

NOVA operates on a strategic bootstrapping model to maximize technical performance while maintaining a lean budget. As a first-year team, we managed all project expenses through structured planning, budget tracking, and cost control. A detailed budget was established early to organize and monitor costs, with all purchases recorded and reviewed to ensure transparency and accountability. We prioritized smart procurement by comparing high-end subsea components with cost-effective alternatives that provide similar performance. Additionally, we emphasized sustainability by integrating repurposed materials, reducing costs while maintaining structural integrity. In-house 3D printing was also used to produce custom components such as Kort nozzles and specialized mounts, enabling efficient and low-cost manufacturing. A detailed budget breakdown and expense report are included at the end of this document for full financial reference.

LOGISTICS

Effective logistics planning was essential to ensure the smooth progress of the Nemo ROV project, covering both material acquisition and transportation arrangements.

Materials Procurement and Management

The team adopted a flexible approach to sourcing materials based on availability, cost, and urgency. A portion of the required electronic components and hardware was purchased from **Ram Electronics** and **Makers Electronics**, which provided reliable access to essential items such as sensors, connectors, wires, and control modules. These suppliers were selected due to their reputation, product availability, and reasonable pricing.

In addition to purchased components, the team optimized resource utilization by borrowing certain tools and materials from team members. This included items such as soldering equipment, testing devices, and some mechanical parts. This strategy helped reduce overall costs and ensured that progress was not delayed due to limited budgets or unavailable components.

To maintain organization, all materials were cataloged and stored systematically. Team members were assigned responsibility for tracking borrowed items and ensuring their safe return. Critical components were handled with extra care to avoid damage, especially during assembly and testing phases.

Transportation and Mobility

Transportation planning focused on both daily operations and competition requirements. Locally, team members coordinated to transport materials and partially assembled components between workspaces using personal arrangements, ensuring flexibility and efficiency.

For the competition phase, the team planned travel from **Aswan** to **Alexandria**, where the event will take place. This long-distance journey required careful preparation to ensure the safe transport of the ROV and all supporting equipment. Protective packaging solutions were implemented to prevent damage to sensitive electronics and mechanical structures during transit.

Additionally, the team accounted for potential logistical challenges such as travel time, equipment handling, and coordination upon arrival. Necessary tools, spare parts, and documentation were prepared in advance to ensure readiness for any unexpected issues during the competition.

Overall, the logistics strategy emphasized efficiency, cost-effectiveness, and reliability, enabling the team to maintain steady progress and ensure full preparedness for competition participation.

TESTING & TROUBLESHOOTING

The team implemented a structured testing and troubleshooting methodology to ensure the reliability and performance of the ROV. Testing was conducted progressively at both subsystem and full-system levels, allowing issues to be identified early and resolved efficiently. Each subsystem—mechanical, electrical, and control—was tested individually before integration, followed by full system validation under simulated operating conditions.

Troubleshooting Strategy & Debugging

The team tested the ROV through a structured and progressive process to ensure safe and reliable operation:

- **Component-Level Testing:**

Each part of the ROV was tested individually before full assembly. Motors were tested separately to confirm correct rotation and response. Electrical connections were checked to ensure proper wiring and stable operation.

- **Subsystem Testing:**

After individual validation, subsystems (mechanical, electrical, and control) were tested together. For example, motors were tested with their drivers and control signals to confirm proper interaction.

- **Water Testing:**

The ROV was tested in controlled water conditions (such as a tank or pool). This allowed the team to evaluate buoyancy, stability, waterproofing, and movement performance under real operating conditions.

- **Full System Testing:**

After successful subsystem tests, the complete ROV was assembled and tested while performing basic tasks such as moving, maintaining stability, and operating the gripper.

- **Troubleshooting Approach:**

When issues occurred, the team used a step-by-step debugging method:

- Observing the problem (e.g., motor not responding, unstable movement).
- Isolating the issue by testing components individually.
- Checking connections, power, and signals.
- Fixing the issue and retesting to confirm the solution.

This structured approach allowed the team to quickly identify and resolve problems without unnecessary disassembly.

Rigorous Subsystem Testing

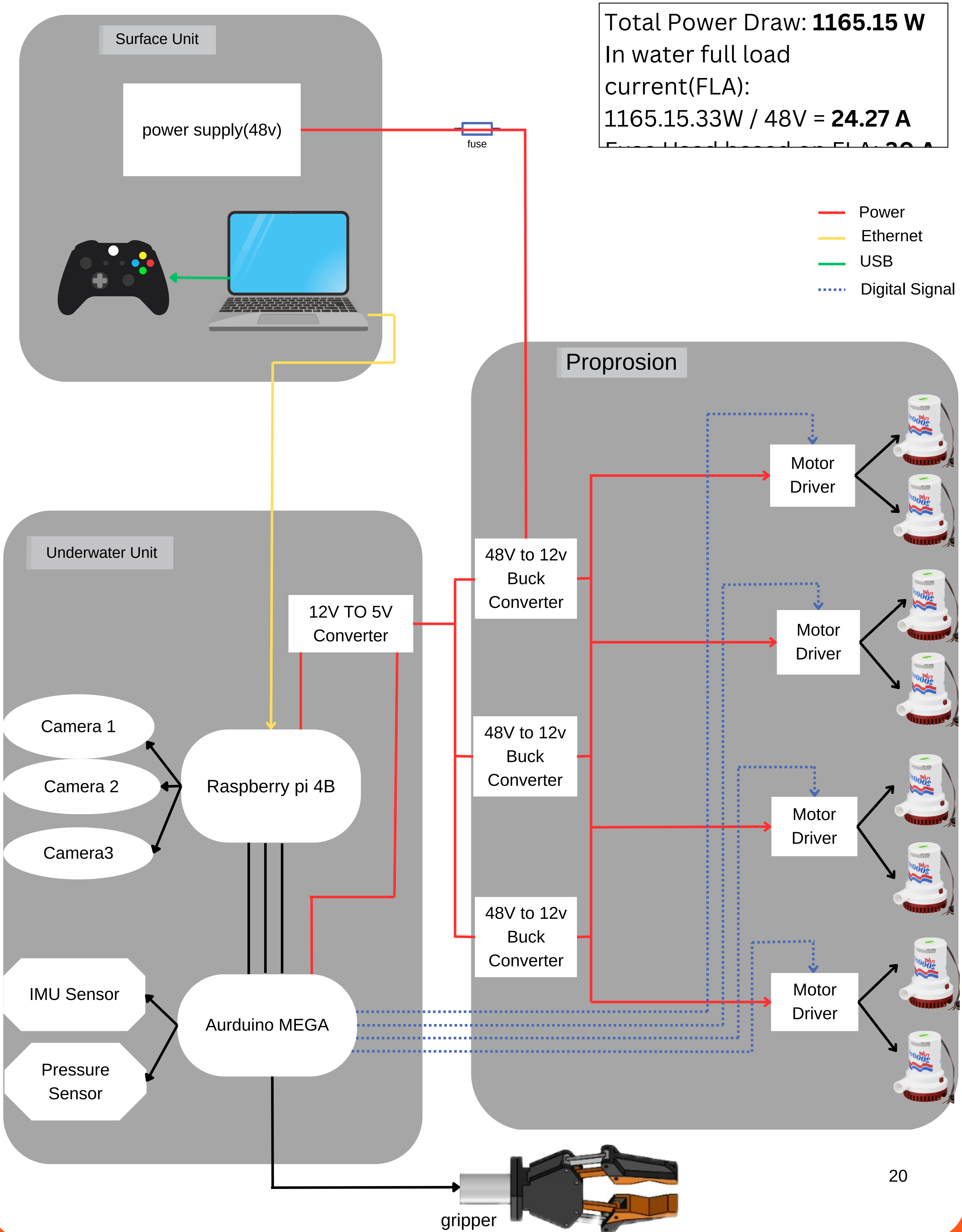
To ensure reliability and performance, the team conducted several practical tests on different subsystems:

- **Waterproofing and Sealing Tests:** The electronics enclosure was tested under simulated pressure conditions to check for leaks and ensure the integrity of the sealing before real operation.

- **Power Distribution Testing:** The team tested the system under different load conditions to verify that the power supply and distribution could handle the current demands of the thrusters and other components without instability.

- **Gripper Testing and Improvement:** Multiple prototypes of the gripper were tested to evaluate grip strength and reliability. Based on testing results, adjustments were made to improve its performance, such as refining the mechanism and enhancing contact with objects.

ELECTRICAL SID



LESSONS LEARNED

Technical Growth

The team developed their engineering skills by working on systems that required practical learning and continuous improvement:

- **Mechanical Design & Sealing:** The team improved their ability to design and assemble components with proper sealing techniques to prevent water leakage, especially around motors and moving parts such as the gripper and valve mechanism.
- **Power Management:** Through testing and iterations, the team learned how to manage power consumption more effectively to avoid overheating and ensure stable and reliable operation during missions.
- **System Integration:** The team gained experience in integrating mechanical, electrical, and control components into one working system, improving overall performance and coordination between subsystems.

Management Skills

The project also helped the team strengthen important organizational and teamwork skills:

- **Knowledge Transfer & Mentorship:** Senior members guided newer members through hands-on training and shared experience, helping build technical confidence within the team.
- **Problem-Solving Under Pressure:** The team improved its ability to handle unexpected issues during testing and operation by working together to quickly identify and resolve problems.
- **Team Communication:** Regular meetings and updates helped keep all members aligned, improving coordination and efficiency in completing tasks.
- **Professional Development:** Participation in competitions, presentations, and documentation improved the team's technical writing, communication, and presentation skills.

FUTURE PLANS

Autonomous and Control Systems

The team aims to advance the ROV's control capabilities by developing more intelligent and assisted control features:

- **Closed-Loop Control:** The team plans to move toward closed-loop control systems to improve stability and reduce pilot workload by automatically correcting system behavior based on feedback.
- **Position & Depth Hold Mode:** A feature that will allow the ROV to maintain its current depth and orientation, helping the pilot focus on precise tasks such as object manipulation.
- **Autonomous Assistance:** Future development will include basic autonomous features to assist navigation and reduce manual control effort, especially in repetitive or stable tasks.

Hardware and Mechanical Upgrades

The team plans several improvements to enhance performance, efficiency, and reliability:

- **Custom PCB Design:** Transitioning to a unified custom PCB to reduce wiring complexity, improve organization, and increase system reliability.
- **Material Optimization:** Exploring the use of lighter and stronger materials to improve maneuverability and overall efficiency of the ROV.
- **Improvved Manipulation System:** Upgrading the current gripper into a more advanced manipulation system with greater flexibility and control for complex uwnderwater tasks.
- **Buoyancy & Stability Improvements:** Developing a more effective ballast or buoyancy system to ensure better stability and control during operation.

ACKNOWLEDGEMENTS

Our operations and the development of Nemo would not be possible without the extensive support we have received this year. We are incredibly grateful, and thank the following organizations and people for their contributions:

- Many thanks to the **MATE ROV Competition** for organizing this event and creating opportunities for students to design and build ocean technologies,
- **The Arab Academy for Science, Technology, and Maritime Transport (AASTMT) – South Valley Campus in Aswan** for their continuous backing and academic support,
- **Dr. Mohamed Taha, Head Of Mechanical Department**, for his unwavering mentorship, generous financial and moral support, and for always being available to patiently answer our questions and guide us whenever we reached out to him,
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- The Mechatronics, Mechanical, and Communications Labs for keeping their doors open and providing our primary workspace, tools, and assembly environment.

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APPENDIX

Appendix A (Safety Checklist)

Category	Check Item	Status
Personnel / Team	All team members wear safety glasses	☐
	Appropriate footwear (closed-toe shoes) worn	☐
	Only trained members handle electrical or power tools	☐
	Everyone knows emergency procedures	☐
Equipment / ROV – Structural	All edges of the ROV frame are smoothed or protected	☐
Category	Check Item	☐
Personnel / Team	All team members wear safety glasses	☐
	Appropriate footwear (closed-toe shoes) worn	☐
	Only trained members handle electrical or power tools	☐
	Everyone knows emergency procedures	☐
Equipment / ROV – Structural	All edges of the ROV frame are smoothed or protected	☐
Category	Check Item	☐
Operational – Pre-Operation	ROV components are secure and stable	☐
	Testing area is clear of obstacles or hazards	☐
	Sensitive objects nearby are protected	☐
	ROV is monitored at all times	☐
Operational – During	Hands, tools, and loose items kept away from moving parts	☐
	Established operating procedures followed	☐
	Power turned off before touching ROV	☐
Operational – Post-Operation	Workspace cleaned and organized	☐
	Any issues, damages, or unusual behavior documented	☐

Appendix B (Laboratory Safety Policy)

- **Supervision:** All lab work must be conducted under supervision. Independent operation is not allowed.
- **Protective Equipment:** Safety glasses and closed-toe shoes are mandatory at all times. Loose clothing and accessories are prohibited.
- **Equipment Authorization:** Only trained members may operate machinery such as drills, lathes, and cutting tools.
- **Workpiece Handling:** Materials must be secured using clamps or vises. Never hold materials by hand during machining.
- **Chemical Safety:** Adhesives, epoxy, and soldering must be used in well-ventilated areas following safety guidelines.
- **Emergency Awareness:** All members must know the locations of fire extinguishers, first aid kits, and emergency shutoffs.
- **Incident Reporting:** Any injury, malfunction, or near-miss must be reported immediately.
- **Uncertainty Rule:** If unsure about any tool or procedure, stop work immediately and seek guidance.

APPENDIX

Appendix C (Power Calculations)

Electrical Load Breakdown

Component	Model	Quatity	Voltage	Unit Max Current	Total Max Current	Config Current	Total Max Power	Total Config Power
Thrusters	Bilge Pump	8	12	8.5	68	57.8	816	799.88
Motor Drivers	Cytron SmartDrive	4	12	0.05	0.2	0.2	2.4	2.4
Main Processor	Raspberry Pi 4B	1	5	3	3	3	15	15
Embedded MCU	Arduino Mega 2560	1	5	0.5	0.5	0.5	2.5	2.5
Stereo Vision	Intel RealSense D435i	1	5	1.5	1.5	1.5	7.5	7.5
Navigation Cams	HD USB + Pi Cam 3	2	5	0.6	1.2	1.2	6	6
Illumination	CREE U1 LED Spots	2	12	1.25	2.5	2.5	30	30
Manipulator Motor	JGA25-370 Geared	1	12	2	2	1.7	24	24
Manipulator Servo	MG996R (Wrist)	1	5	2.5	2.5	2.1	12.5	12.5
Sensors & Fans	IMU / Pressure / Cooling	3	5	0.2	0.8	0.8	4	4
TOTAL POWER							919.9 W	903.58 W

Power Transmission and Main Fuse

System Parameter	Specification / Origin	Value
ROV Nominal Power Demand	Total Configured Power from Subsea Load	919.9W
DC-DC Converter Losses	Assuming 85% Conversion Efficiency	161.95 W
Tether Power Losses	20 m Length, 4 mm² Copper Wire	83.30 W
Total Top-Side Power	Required from 48V Surface Supply	1165.15 W
in water full load Current (FLA)	At 48V Top-Side (1165.15 W / 48V)	24.27A
Recommended Main Fuse	Including +25% Safety Margin	30 A

BUDGET SHEET

Category	Type	Item	Description	Quantity	Price per	Total Price
Power	Purchased	Power Supply	High-capacity AC-DC unit for surface station power	4	425 EGP	1700 EGP
Power	Purchased	Power Cable	Grounded 3Å—0.75mm AC supply cable for safety compliance.	1	25 EGP	25 EGP
Power	Purchased	AC Power Plug w/	250VAC 10A socket with integrated safety fuse and switch.	1	35 EGP	35 EGP
Power	Purchased	DC-DC Step	Waterproof 360W converter (48V to 12V) for heavy thruster	3	1450 EGP	4350 EGP
Power	Purchased	AA Rechargeable	2300mAh 1.2V cells for portable testing equipment.	10	175 EGP	1750 EGP
Power	Purchased	Battery Charger	C9001 smart charger for maintaining testing power cells.	1	385 EGP	385 EGP
Power	Purchased	Step Down	3.3A adjustable voltage regulator for micro-controller logic.	2	45 EGP	90 EGP
Power	Purchased	Battery Holder 6-	Standard housing for AA battery backup configurations.	2	15 EGP	30 EGP
Mechanical	Purchased	PETG HS	3D printing material for structural thruster mounts and shrouds.	5	500 EGP	2500 EGP
Mechanical	Purchased	Acrylic sheet	camera housing to seal it.	2	170 EGP	340 EGP
Mechanical	Purchased	Lead Screw	Stainless steel T8 screw for gripper actuation.	2	165 EGP	330 EGP
Mechanical	Purchased	Epoxy	2-part high-strength resin for sealing and structural bonding.	5	50 EGP	250 EGP
Mechanical	Donated	PVC Clinyder	Housing for thel electronics of the ROV	1	-	-
Mechanical	Purchased	Composite	Material for the upper frame of the ROV.	1	270 EGP	540 EGP
Mechanical	Purchased	Aluminum Flange	Material for the thermal backplate and custom flanges.	1	155 EGP	155 EGP
Mechanical	Purchased	Acrylic tube	Structural frame sections for float rigidity.	1	400 EGP	400 EGP
Mechanical	Purchased	Syringe	Manual air evacuation tool used to create a vacuum within the	5	30 EGP	150 EGP
Mechanical	Donated	lubrication oil	Marine lubricant for mechanical friction reduction and moisture	1	-	-
Mechanical	Purchased	2000GPH Bilge	12Vdc high-flow motors utilized for 6-DOF vectored propulsion.	8	1750 EGP	14000 EGP
Mechanical	Purchased	O-Rings	Elastomeric compression seals for ensuring watertight integrity	10	25 EGP	250 EGP
Control	Purchased	USB to Mini USB	Data cable for programming Arduino Nano controllers.	1	20 EGP	20 EGP
Control	Purchased	ESP32 Dev Board	WiFi/Bluetooth microcontroller for wireless diagnostic testing.	1	300 EGP	300 EGP
Control	Purchased	joystick	Manuual control interface for ROV movement	1	350 EGP	350 EGP
Control	Purchased	NRF24L01	Wireless transceiver for auxiliary telemetry verification.	2	220 EGP	440 EGP
Control	Purchased	Jumper Wire Set	M-M / M-F / F-F wires for signal routing between boards.	1	500 EGP	500 EGP
Control	Purchased	Raspberry Pi 4	High-level processor for video streaming and vision algorithms.	1	4250 EGP	4250 EGP
Control	Purchased	Arduino MEGA	Main controller for managing PWM signals and sensor interrupts.	1	1250 EGP	1250 EGP
Electrical	Purchased	XT30 Connectors	Compact power connectors for auxiliary electronic	10	50 EGP	500 EGP
Electrical	Purchased	XT60	High-current battery connectors for modular power	6	40 EGP	240 EGP
Electrical	Purchased	RTC	Precise clock for motor synchronization and mission task timing.	1	145 EGP	145 EGP
Electrical	Purchased	JGA25-370	12V DC Gearbox motor for precise gripper linear motion.	2	350 EGP	700 EGP
Electrical	Purchased	L298 Motor	H-Bridge driver for controlling low-power manipulator motors.	1	75 EGP	75 EGP
Electrical	Purchased	Cytron MDD10A	Dual 10A DC motor driver for bi-directional thruster control.	4	1250 EGP	5000 EGP
Electrical	Purchased	Ethernet cable	Network module for reliable communication through the tether.	1	150 EGP	150 EGP
Electrical	Purchased	Cytron MDD10A	Socket strips for mounting microcontrollers to PCBs.	2	15 EGP	30 EGP
Electrical	Purchased	Fuses	Safety fuses for circuit overcurrent protection.	15	5 EGP	75 EGP
Electrical	Purchased	MicroSD Card	High-speed storage for Raspberry Pi OS, control software, and	1	200 EGP	200 EGP
Electrical	Purchased	tether	12AWG (50m) heavy-duty umbilical wiring for surface-to-ROV	50	25 EGP	1250 EGP
Electrical	Purchased	XL4016 Buck	8A Step Down module with digital display for logic power	1	220 EGP	220 EGP
Electrical	Purchased	Heat Shrink	Protective insulation for waterproofing soldered cable	1	50 EGP	50 EGP
Electrical	Purchased	Wagos	Vibration-resistant splicing connectors for power distribution.	1	210 EGP	210 EGP
Electrical	Donated	Power	Surge-protected AC power strip for centralized surface station	1	-	-
Electrical	Purchased	Waterproof LED	Provides illumination for underwater visibility	1	375 EGP	375 EGP
Sensors	Purchased	Tempruture	Float thermal sensor.	1	60 EGP	60 EGP
Sensors	Purchased	BNO055 IMU	9-axis Absolute Orientation sensor for active stabilization.	1	3100 EGP	3100 EGP
Sensors	Purchased	Pressure Sensor	Analog depth sensor for real-time mission telemetry.	2	1550 EGP	3100 EGP
Tools	Purchased	Welding/Solder	High-conductivity lead for high-quality solder joints.	1	185 EGP	185 EGP
Tools	Purchased	Soldering Tool	Precision iron for secure electrical circuit bonding.	1	225 EGP	225 EGP
Vision	Purchased	Raspberry Pi	HD camera modules for navigation and task monitoring.	1	490 EGP	490 EGP
Vision	Donated	Camera	Digital web camera (Gammaa)	1	-	-
Vision	Purchased	stereo camera	Spatial AI camera for depth perception and hardware-	1	16000 EGP	16000 EGP
General	Cash	Fund support	Mechanical Department Fund (Dr. Mohammed Taha),	1	-	-
General	Purchased	Branding	Team branding and uniform production, including logo design.	18	150 EGP	2700 EGP
Travel	Donated	Train cost	Team and equipment transportation (Rail).	18	-	-
Total						64,120 EGP