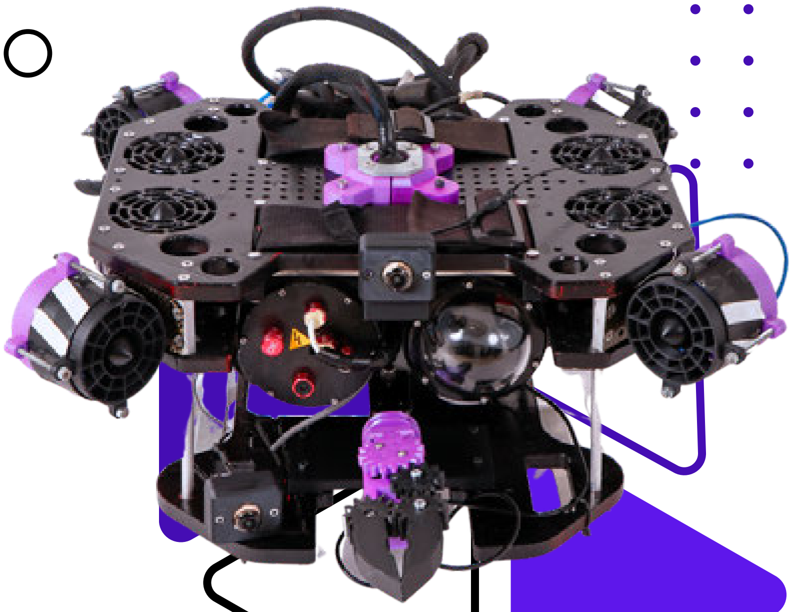
TECXOTIC

TECHNICAL REPORT 2024

XOCHITEPEC, MORELOS, MÉXICO

TZILACATZIN



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HECHO EN MEXICO

Tecnológico de Monterrey

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Glosary

Abstract:

- ROV: Remotely Operated Vehicle.
- MATE: Marine Advanced Technology Education.

Safety:

- PPE: Personal Protective Equipment
- SDS: Safety Data Sheets
- JSA: Job Safety Analysis
- SOP: Standard Operating Procedure
- RFP: Request for Proposal Frontend: Web interface.

Software:

- Backend: Layer of access to the data and the technological logic, hidden from the user.
- OpenCV: Open Source library for computer vision.
- HTTP: Protocol that allows transferring information Websocket: Protocol to communicate devices on a bidirectional manner
- REST API: A web architecture that determines the rules on which devices can connect

Design and Mechanics

- RFP: Request for Proposals
- SMW: Simple, Modular, and Well-done
- Reynobond® : Aluminum Composite Panel
- MDF: Medium Density Fibreboard
- CNC: Computer Numerical Control
- CAD: Computer-Aided Design
- CAE: Computer-Aided Engineering
- DOF: Degrees of Freedom

Electronics:

- SMW: Simple Modular Well-done
- GCU: The Ground Control Unit
- TCE: The Thruster Control Enclosure
- MCE: The Main Control Enclosure
- ESC: Electronic Speed Controller PCB: Printed Circuit Board CCU: Case-Control Unit A

1. Abstract

To mitigate climate change, it is crucial to address emerging issues with innovative and affordable solutions. These include preserving ecosystems like coral reefs, identifying healthy habitats for species such as lake sturgeon, and deploying observation assets for data collection.

Since its foundation, TecXotic has focused on building ROVs to address global ocean challenges. Each year, the company strives to enhance its products, applying the experience gained over nine years. This season, the team comprises 21 members, 19 of whom are new, presenting the challenge of integrating a majority of rookies. Despite this, the final product, Tzilacatzin, showcases innovative ideas, knowledge from past failures, and the efforts of former members. Named after an Otomí hero from the fall of Tenochtitlán, Tzilacatzin symbolizes the courage and resilience of the TecXotic team.

Tzilacatzin is built to stringent quality and safety standards, featuring a modular design inspired by the previous product Atzin, innovative tools, and scalable, reliable software. This technical report details the processes and results, comparing them to previous work. With these improvements, TecXotic aims to provide a competition-ready ROV and contribute to marine industry research and development for the ocean we need, to the future we want.

Fig. 4 "Tecxotic 2024"

2. Safety

A. Safety Philosophy

Safety is the top priority for TecXotic. It encompasses collaborators, potential customers, marine wildlife, and the environment, all equally important. This level of importance is fundamental since it provides collaborators with total confidence and comfort, allowing correct manufacturing processes, task completions, and hazards avoidance. TecXotic promotes and ensures a safe, organized, and clean work environment for all involved.

B. Laboratory and Workshop Safety Protocols

For this year, leveraging Notion, an improved version of our safety handbook has been developed, granting quick safety reviewing at any moment and allowing constant revisions. Safety Awareness remains a key aspect, with comprehensive safety information, protocols, and manufacturing procedures available through Notion. This includes Job Site Safety Analysis (JSA), Safety Review and Safety Analysis.

Safety review

Task	Date	Prio...	Document
Montaje de Circuit Boards	May 15, 2024	High	Expected Work Practices
Cableado de Circuit Boards	May 15, 2024	Medium	Expected Work Practices
Cableado Oculto	May 15, 2024	Medium	Expected Work Practices
Ordenamiento de Cables	May 15, 2024	Low	Expected Work Practices
Cubierta de Cables	May 15, 2024	Medium	Expected Work Practices
Encapsulamiento de Dispositivos	May 15, 2024	High	Expected Work Practices
Uso de Baterías	May 15, 2024	Medium	Expected Work Practices
Sello de Motores Brushless	May 15, 2024	High	Sealing Brushless Motors
Cobertura de soldaduras	May 15, 2024	Medium	Sealing Brushless Motors
Safety Requirement	May 15, 2024	Low	Sealing Brushless Motors
Prueba de MegaOhms	May 15, 2024	Low	Sealing Brushless Motors
Seguridad con el Megger	May 15, 2024	High	Sealing Brushless Motors
Fusible Anderson y Conectores	May 15, 2024	Medium	Initial Safety Inspection
Visualización de Control Box	May 15, 2024	High	Initial Safety Inspection
Aliviado de Tensión en el ROV	May 15, 2024	High	Initial Safety Inspection
Hélices Cubiertas en el	May 15, 2024	High	Initial Safety Inspection

Fig. 5 “Notion Safety Review rubric”

With Notion, an improved version of last year’s safety handbook has been implemented, allowing quick access for all safety requirements and specifications. We implemented rubrics that facilitated easier safety checks every time we carried out any work.

C. ROV Safety Protocols

TecXotic designed JSAs to guarantee the proper handling of Tzilacatzin, facilities, equipment, and resources. A safety checklist, integrated into the JSA, was developed for pre-immersion and post-immersion procedures, minimizing accidents or mishandling during Tzilacatzin operation and transportation. This is crucial for ensuring the safety, well-being, and physical integrity of collaborators and operators. Additionally, with the aid of Notion, we introduced rubrics to streamline safety assessments whenever tasks were performed.

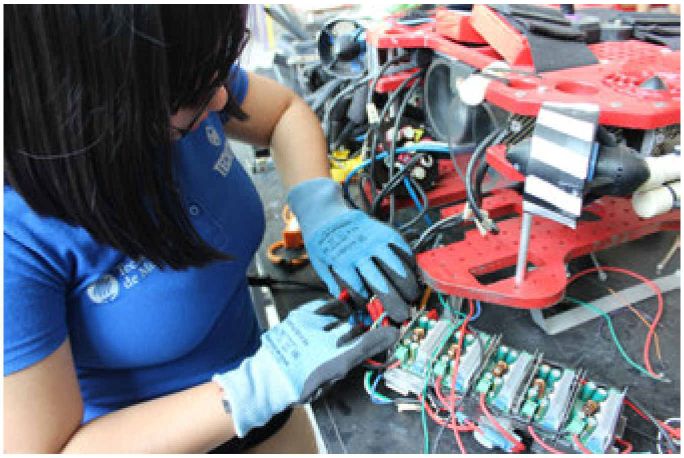

Fig. 6 “Safety Laboratory Protocols”

D. Training

All collaborators must undergo general training, and depending on their field of work, specialized training. These training programs promote safety awareness, reduce accidents, and promote adequate working environments and good practices in the lab and the field.

General training includes but is not limited to: lab use, power tools and machinery, basic procedures

and manufacturing processes. Additionally, TecXotic conducted 17 training courses in collaboration with Corporate Responsibility and other internal or external organizations of Tecnológico de Monterrey.
Parallel to all training, a peer-to-peer system is followed. Collaborators are constantly looking out for each other's safety and sharing their learnings, promoting the well-being and physical integrity of other collaborators.

E. Safety Features

The ROV features 3D printed PLA guards for the thrusters to avoid collisions with the propellers. Enclosure penetrators are sealed according to the Safety Handbook's SDS, while the frame is designed with stability in mind.

Fuse calculations for the ROV and non-ROV devices ensure proper electrical operation, while the implementation of a Main Emergency Stop Button accessible to the operators at all times stops all operations and helps to prevent accidents.

Tzilacatzin has a series of safety features that comply with MATE and TecXotic's safety requirements. These include design, manufacturing processes, and operations. These features are categorized into ROV, Software, and Operator safety.

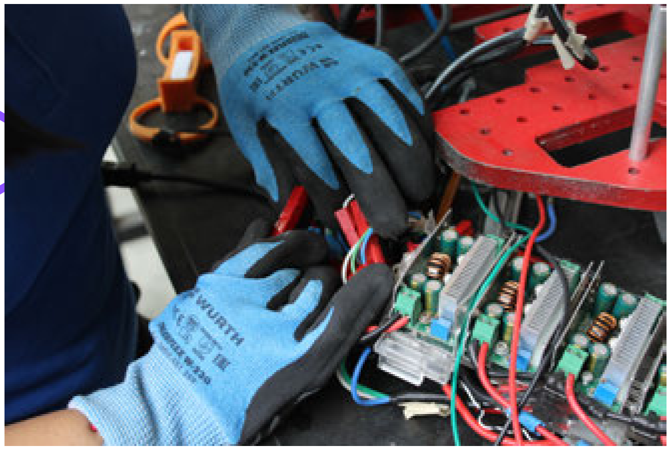

Fig. 7 "Safety Laboratory Protocols"

3. Design Rationale

A. Design Overview

TecXotic's latest product, the Atzin 2.0, has proven to be the most reliable and modular, fully utilizing the mechanics propelled by its eight thrusters. Therefore, the decision was made to retain the existing design rather than starting from scratch and discarding a functional and effective design.

Recycling does not mean that there were no quality requirements in place to achieve improvements throughout the season. After conducting various Failure Mode and Effect Analysis (FMA) for the Atzin 2, specific design guidelines and recommendations were established for the Tzilacatzin.

1. **MAINTAIN** ⚓ Safety practices & protocols.
2. **MAINTAIN** ⚓ Adjustable buoyancy.
3. **INCREASE** ▲ Frame's rigidity.
4. **DECREASE** ▼ Assembly complexity.
5. **DECREASE** ▼ Prototyping time.
6. **IMPROVE** ⚙ Tool reliability and power.
7. **IMPROVE** ⚙ Software reliability.

Fig. 8 "Failure Mode and Effect Analysis"

Appendant 1 - Season Acomplishments

B. Design Philosophy

A key component of TecXotic's design philosophy, which has driven the reduction of prototyping and assembly time while enhancing each iteration of their ROVs, is the SMW (Simple, Modular, and Well-done) methodology. This approach has been implemented in every area and subsystem to holistically enhance each characteristic of the Tzilacatzin.
Simple: Designs must be as simple as possible, incorporating only the necessary features for each piece. A design with fewer parts has a lower probability of errors, defects, and failures.

Modular: A modular design allows for easy repairs, adjustments, and changes, establishing a standard of quality for all pieces, components, and assemblies. This approach also facilitates the strategic manufacturing of spare parts for competitions, minimizing the total amount of equipment the team needs to transport.

Well-Done: This component integrates with the other two to focus on the quality of the designs, specifications, and manufacturing, ensuring the highest possible quality.

Another crucial, yet often unmentioned, factor is the experience gained over the years. Each participation and product has provided valuable lessons: In TecXotic's very first ROV, the handmade thrusters caused reliability issues with movement. The initial iteration of the Atzin suffered from deformation due to a lack of structural strength. More recently, the reliability of the latest tools was compromised by issues with their power source.

All past experiences have contributed to the design and development process for the Tzilacatzin. Each ROV produced by TecXotic aimed to improve upon its predecessor and avoid repeating past mistakes. This has led to the establishment of an ever-growing list of guidelines that enable team members to fully utilize their potential and creativity while avoiding previous errors.

Fig. 9 "Tzilacatzin isometric view"

4. Project Management

A. Company Organizations and Assignments

TecXotic is divided into six main departments: Design, Electronics, Software, Corporate Responsibility, Safety, and Social Media. Each department has a department lead, who oversees tasks assignment for the area and setting deadlines for each activity while maintaining direct contact with the other areas to develop integrated systems that ensure the overall functionality of the ROV and a focused workflow. Every department actively participates in documentation, preventing the need for a dedicated documentation area and mitigating communication mistakes between department developers and third parties. At the start of the season, a recruitment campaign was conducted, and now we have approximately 30 members in total interested in the different areas of the project.

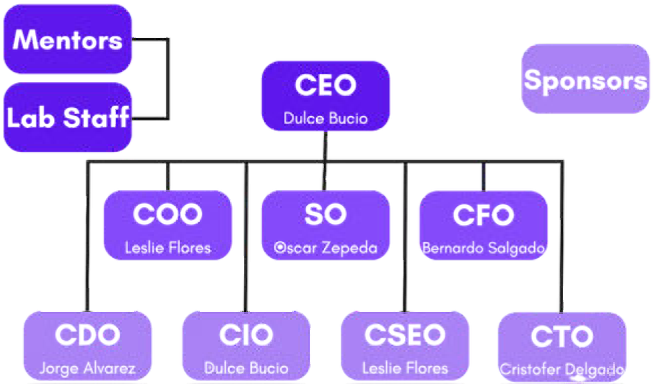

Fig. 10 "Company organization"

B. Project Management

TecXotic holds general weekly meetings involving all areas. In these meetings, the team defines what tasks are complete, reviews the work accomplished that week, sets new priorities, and identifies new tasks to be done.

C. Workflow

The workflow is established weekly by the Department Leaders, who assign specific tasks to every team member and set specific milestones for each task to be accomplished by the end of the week. Each task is given a deadline, and if the deadline is missed, the task is prioritized. This method ensures that every department achieves significant and measurable progress each week.

D. Collaborative Workspace

This year, we used Asana for the first time. This new tool allowed us to visualize dependencies more clearly and divide the project into six distinct areas, ensuring that everyone knew their specific tasks without excessive visual clutter. In addition to Asana, we continued to use Google Workspace for document storage and real-time collaboration. Google Workspace houses the company's database, which contains information about every season and ROV constructed, it also facilitates collaborative document creation and editing. Moreover, tools like Zoom were used for online meetings when necessary, allowing screen sharing to facilitate information sharing and problem-solving when team members were not physically present in the same location. We also found that Asana's ability to integrate with other tools streamlined our workflow and enhanced overall productivity.

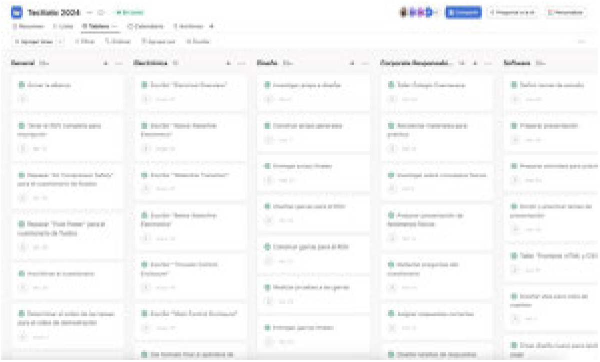

Fig. 11 "TecXotic's Task Board"

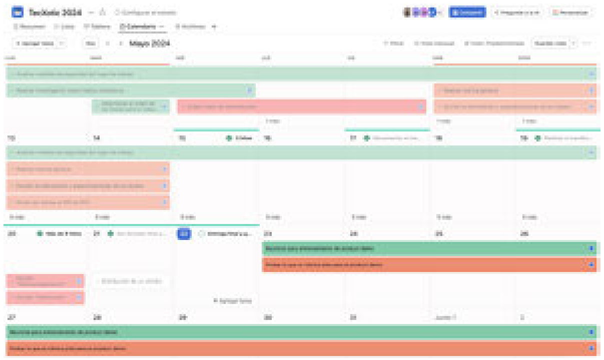

Fig. 12 "TecXotic's Calendar"

E. Code Management

The company uses GitHub to host the backend and frontend repositories. We maintain good practices and organization by using branches to develop code, which is later reviewed before being added to the main branch. This approach helps maintain clean code that works consistently, avoiding significant crashes or issues that would require the entire codebase to be checked.

5. Budget & Cost Planning

Given the company's limited budget, many components from previous designs were reused to reduce the ROV's production costs. Each department was allocated an individual budget, which was closely monitored to ensure all expenses were reported to the Finances Department. The primary focus when purchasing new components was to ensure they met specific functionality and reliability standards and were relevant to tool development. Employee transportation costs were not considered, as these expenses are covered individually.

Appendant 2 - Budget data

6. Mechanics

A. Mechanical Overview

Additive manufacturing remains essential for constructing the ROV, allowing the creation of complex geometries and precise tolerances at a much lower cost than other methods. With regards to the mechanical modularity, the strategic decision was made to continue using last year's model due to its numerous advantages and the desire to continue maximizing its proven effectiveness. This approach not only reflects our pursuit of efficiency and resource optimization but also demonstrates our commitment to sustainability by reducing waste and minimizing the environmental impact associated with producing new components. Additionally, maintaining the same mechanical modularity allows for greater continuity in design and manufacturing, simplifying production processes and ensuring smoother integration of new mechanical and technological improvements. Tecxotics' decision was also based on confidence in the durability and strength of the existing design, which proved its worth in last year's competition.

Safety continues to be TecXotic's top priority. Safety design protocols and operational procedures were meticulously followed to ensure every aspect of the vehicle meets the safety standards outlined in the RFP.

B. Frame

This year's ROV is a refinement and enhancement of last year's model due to the significant potential recognized by the TecXotic team in the original proposal. The main mechanical parts for this edition include a gripping mechanism for essential components, reinforcement of structural areas that showed deformation at the end of last season's MATE ROV Competition, and improved internal component layout to reduce empty spaces. TecXotic's dedication to environmental sustainability and continuous innovation led to another major improvement in the frame: the ongoing use of "PolyAl", a sustainable Cellulose-Aluminum-Plastic Composite material. The tool deck was also made of PolyAl, which has resulted in increased stability and flotation due to its unique properties. This material offers several advantages, the foremost being that it is made from 100% recycled material; producing one kilogram of PolyAl requires 140 multilayer "Tetra-Pak" containers. Additionally, PolyAl is waterproof, impact-resistant, flexible, and has a density ranging from 0.98 to 1.1 g/cm^3, making it neutrally buoyant and not affecting the ROV's flotation.

C. Propulsion Layout

The eight-thruster configuration remains a crucial element of TecXotic's ROV design, offering excellent maneuverability with enhanced displacement and precision for underwater tasks. Tzilacatzin, like its predecessor, exclusively uses Blue Robotics® T200 Thrusters. According to the manufacturer's data, each thruster propeller spins at 1,676 rpm and generates approximately 1.5 kgf of thrust with a power consumption of 54.4 W at 16.0 V. This setup provides sufficient thrust for horizontal and vertical motion without requiring the thrusters to operate at full throttle, thereby reducing power consumption and extending their lifespan. The propulsion system supports movement along three perpendicular axes (surge, sway, heave) and rotation around one axis (yaw). Ensuring stability along the heave axis is a priority, necessitating four thrusters at the same height. Four of the eight T200 thrusters are mounted horizontally at each corner of the frame, angled at 45°.

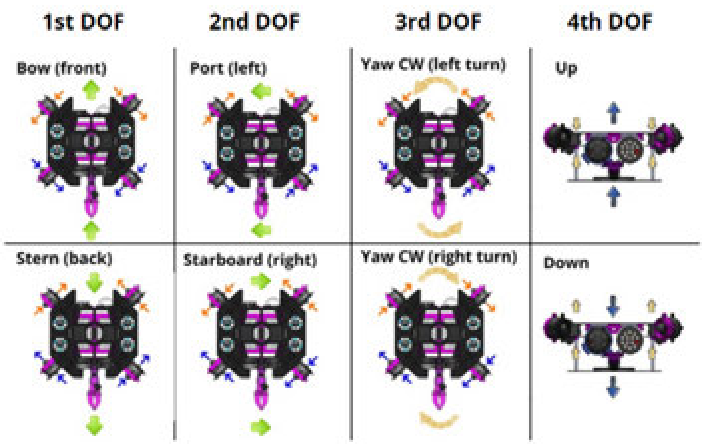

Fig. 13 "Thrusters Directions"

D. Electronic Enclosure

The electronic housing consists of two cylindrical acrylic containers from Blue Robotics (Watertight Enclosure for ROV 4" series). TecXotic chose these components for their affordability, reliability, and versatility instead of developing custom solutions. Rated for depths of up to 100 meters, the cast acrylic tubes provide ample space for electronic components. The transparent material allows for the use of cameras and facilitates visual inspection. Hermetic sealing is achieved with O-ring seals on the end caps and penetrators that seal the electrical cables as they enter the enclosure.

As part of the safety protocol, a vacuum test is performed before each poolside operation, according to the company's Job Safety Analysis (JSA). The internal pressure of each enclosure is reduced to -15 bar (equivalent to a depth of 152.9 meters of seawater) and must remain stable for 15 minutes without increasing more than 3 bar.

The cylindrical containers offer several advantages, including a variety of end caps and even stress distribution. In the current ROV configuration, different end caps are used to meet various needs: an optically clear acrylic dome is ideal for camera visibility, while aluminum end caps with holes and penetrators handle external connections. The circular shape evenly distributes stress along the cylinder, avoiding the shear stress found in square enclosures.

E. Bouyancy

The unpredictability of conditions in environments such as rivers, lakes, and other marine settings led TecXotic to carefully consider how the buoyancy of Tzilacatzin should function. Buoyancy is the upward force exerted by any liquid on a submerged object due to pressure, as illustrated in the free body diagram below. Maintaining zero to slightly positive buoyancy is crucial for safety, preventing Tzilacatzin from becoming stuck at the bottom if the motors fail. However, this buoyancy must remain low to ensure the motors do not require excessive power to move the ROV. The design takes this into account, and each time a new version is developed, a spreadsheet is used to calculate its buoyancy so that weights or floats can be added to adjust floatability.

Aligning the center of mass with the buoyancy center is essential to ensure the vehicle's stability, making it easier to operate tools and complete tasks. To achieve this, the mass must be evenly distributed on both sides of Tzilacatzin, and they must also displace the same volume of liquid. A buoyancy analysis was conducted using experimental data and the Archimedes principle, considering measurements such as the ROV's weight and volume. The CAD model for this specific task and the floatability system were analyzed to determine the force exerted on Tzilacatzin.

Volume	0.006713145	Obtained from SolidWorks
Liquid density	992	External data investigation
Buoyancy (N)	65.32910366	Density and volume from liquid
ROV mass (kg)	17.74	Meassuring
ROV weight (N)	174.0294	gM ROV mass
Flotability (N)	-108.7	$Buoyancy - W_{ROV}$
Bouyancy needed to achieve neutral buoyancy	108.7	

Fig. 14 "ROV's Physical Metrics"

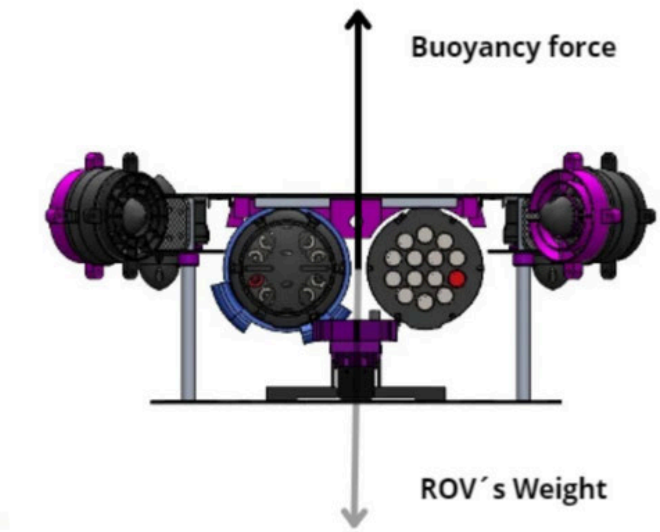

Fig. 15 "Buoyancy Physical Explanation"

F. Tensor Relief

The tensor relief is positioned at the top of Tzilacatzin, featuring a 3D printed ball with a clamp/headband that secures the cable. When the cable is pulled, the ball remains stationary. This ball fits into a small, octagonal shape connected to the frame of Kolop (a previous design) with graf nuts and screws. When the tether is pulled, the force is transferred from the ball to the octagon, and finally to the frame. This setup ensures that tension is shifted from the cable to the frame without risking damage to the connections, while allowing cable movement. This design helps Tzilacatzin maneuver easily in marine environments.

An important aspect of this setup is the use of PETG (Polyethylene Terephthalate Glycol) material in the support structure. PETG is known for its high strength, durability, and resistance to water and chemicals, making it ideal for marine applications. The inclusion of PETG enhances the overall reliability of the tensor relief system by providing a robust support that can withstand the harsh conditions of underwater environments. Its resilience ensures that the connections remain secure, and the material's flexibility helps absorb and distribute the forces exerted on the cable, reducing the risk of fractures or deformations.

Consequently, using PETG in the support structure significantly benefits the tensor relief, contributing to Tzilacatzin's efficient and safe maneuverability in marine settings.

E. Enclosure Supports

Flexible bands secure the electronic enclosures in place, offering two advantages over previous solutions. First, they simplify the removal of the enclosures, eliminating the need to loosen screws or use specialized tools. Second, they apply uniform pressure over a larger area, reducing the risk of stress concentration on these critical components.

F. Thruster Guards

The thruster guards were designed in Solidworks for the side thrusters, which handle surge, sway, and yaw movements, and for the upper and lower parts of the thrusters responsible for heavy movement. These guards are integrated into the frame to minimize the use of 3D printed parts and to leverage the mechanical properties of "PolyAl," thereby reducing assembly complexity. They are specifically designed to cover the motors, preventing unwanted objects such as coral fragments or aquatic life from colliding with the propellers.

7. Electrical & Electronics

A. Electrical Overview

Tzilacatzin's overall electrical system leverages the advancements of previous years, adopting a more systematically distributed and accessible design while maintaining a steadfast commitment to the SMW philosophy. As such, the general structure closely mirrors Tzilacatzin's, comprising three primary components: the Above the Waterline unit (GCU), facilitating operator-ROV interaction; the Below the Waterline section (housed within two electronic enclosures), where tasks like voltage regulation and distribution occur; and the Tether, exclusively utilized for communication and primary power supply. The arrangement of electronics within these enclosures is engineered for swift problem identification and component replacement. In line with TecXotic's strategy to streamline Tzilacatzin's operation, pneumatic and hydraulic systems are eschewed, eliminating fluid conduits through the Tether and the additional complexities (such as pressure gauges) that would necessitate monitoring by GCU operators. Conversely, an octet of thrusters is once again employed to maximize displacement capacity, deliver uniform thrust in all directions, and ensure exceptional maneuverability despite Tzilacatzin's dimensions. Specifically, eight T200 BlueRobotics® thrusters are integrated for optimal performance. Consequently, Tzilacatzin operates at peak efficiency with an average current consumption of amperes.

B. Above Waterline Electronics - Ground Control Unit (GCU)

The GCU is the main station where operators interact with Tzilacatzin and the software interface. It incorporates multiple displays to present data from two key elements: 2 digital cameras linked to the main on-board processing unit (NVIDIA Jetson Nano) for software and image processing, and 4 analog cameras for ROV operations, along with the interface for data input/output to the main software. Safety was paramount in the GCU's design and production, given its extensive human interaction during ROV usage. Thus, it incorporates various safety features, including an emergency stop button that instantly halts the 48.0 V power supply and a (Littelfuse 25.0) A fuse located within 30.0 cm of the main power input (refer to SID for fuse calculations).

Fig. 16 "GCU"

C. Waterline Transition

The Tether serves as the only connection between the GCU and Tzilacatzin, linking to the ROV through TecXotic's proprietary tensor relief mechanism. This design minimizes strain on the cables, allowing the frame to absorb all tension.
The tether is 20.0 meters long and includes only four connection lines: two CAT6 ethernet connections for the processing unit and analog cameras, and two AWG 14 cables for power (live and ground). It is covered with an expandable braided sleeve to reduce entanglement, protect the cables, and facilitate easy handling. The minimal number of cables and strategically placed floats along the tether reduce drag and improve tether management during missions.

D. Below Waterline Electronics. Below Waterline Electronics

The on-board electrical system is contained within two separate electronic enclosures, each handling specific tasks: the TCE manages power and thruster control, while the MCE handles computer processing, image recognition, and tool control. This administration helps isolate power supply issues from those related to the processing unit, tools, cameras, or thrusters. Anderson Powerpole connectors are used within both enclosures for their reliability and high current capacity.

Cables from the Tether, thrusters and communication between enclosures use BlueRobotics® cable penetrators or BlueRobotics® WetLink penetrators whenever possible.

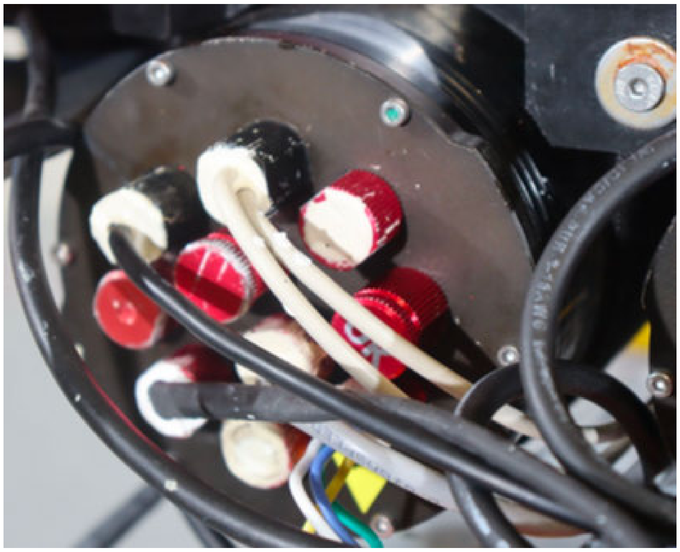

Fig. 17 "Penetrators"

E. Thruster Control Enclosure

The main power supply is provided from the Tether into the TCE. The incoming voltage is distributed to five 200.0 W voltage regulators inside the TCE, all connected in parallel. Four of these regulators step down the voltage from 48.0 V to 16.0 V for the thrusters, controlled through BlueRobotics® standard ESCs. Each regulator powers two thrusters arranged to minimize current consumption and evenly distribute the load on each regulator. The fifth regulator outputs 12.0 V and supplies power to the MCE. The ESCs receive PWM signals to control the thrusters from a Pixhawk 4.

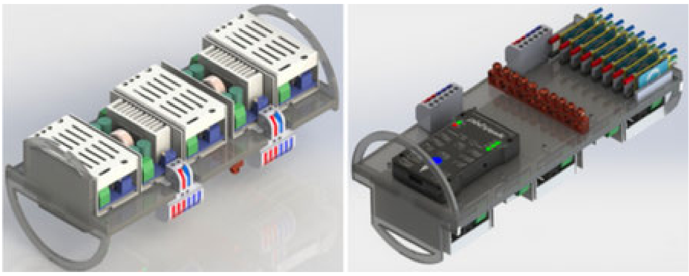

Fig. 18 "TCE"

F. Main Control Enclosure

Power at 12.0 V is received from the TCE and distributed to various components within this enclosure. First, it powers two Micro Servo at 12.0 V, which control the tools. Next, a 12.0 V to 5.0 V step-down module is used to supply power to the main processing unit, an NVIDIA Jetson Nano, and an Arduino Uno. The Jetson Nano handles communication with the GCU, digital cameras, supplies power and data to the Pixhawk 4, and processes the controller's inputs to manage the tools, which is then transmitted to the Arduino Uno via serial communication. Finally, 12.0 V supplies power for the four analog cameras to have a better ROV control visibility to pilots.

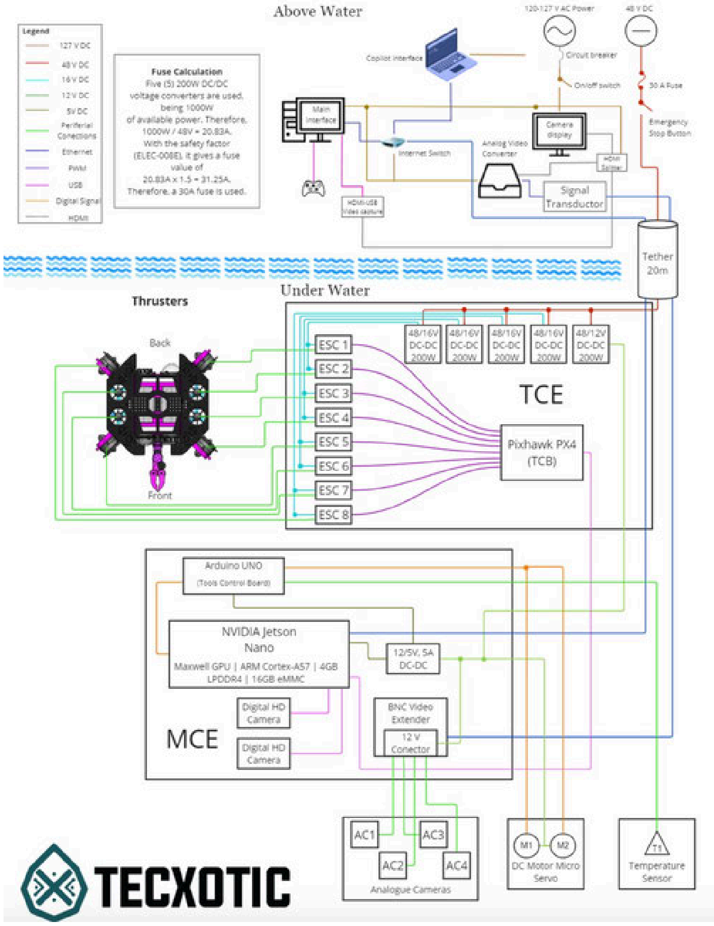

Fig. 19 "SID"

These step-down modules are not only used to achieve the required voltages for the components but also as a safety measure to prevent issues like current spikes from affecting sensitive components like the Jetson Nano. The Arduino Uno serves a similar purpose by preventing a direct connection between the Jetson and the tools.

8. Software

A. Philosophy and Overview

In the previous year, TecXotic's software aimed to create a cost-effective and easily maintainable system that could be reused and would simplify the implementation of enhancements based on new requirements. Reflecting on the achievements and shortcomings of this system, the team has made substantial advancements and improvements to address the upcoming needs we identified throughout this season.

During our review, we identified several sensitive areas, including system performance, security, and user experience. We prioritized these areas and made significant improvements: enhancing system performance for faster response times, strengthening security measures to protect against threats, and refining the user interface for a more intuitive user experience.

These enhancements have resulted in a more robust and reliable software system, better equipped to meet evolving demands and provide a solid foundation for future innovation.

B. Design and Software Architecture

The software architecture of Tzilacatzin is built upon a robust and modular design, which has been refined and optimized over the past year to ensure seamless control, efficient data processing, and reliable communication with the client. The architecture comprises four primary components, each responsible for a specific set of functions:

Core: Tzilacatzin's primary control module, responsible for managing motion, sensor data, and communication with the surface. This module serves as the brain of the ROV, ensuring seamless control and data exchange through:

- Real-time sensor data processing and analysis.
- Motion control and stabilization algorithms.
- Communication protocols for surface communication.

Vision and Autonomy: This module handles all image processing tasks and implements the logic for autonomous driving, enabling the ROV to navigate and make decisions independently through:

- Advanced computer vision algorithms for object detection and tracking.
- Machine learning-based decision-making for autonomous navigation.
- Integration with sensor data for enhanced situational awareness.

Tooling Handler: A fundamental submodule that oversees the control of tools and actuators, allowing for precise manipulation and interaction with the underwater environment through:

- Real-time control of manipulator arms and end-effectors.
- Precise control of actuators for delicate operations.
- Integration with sensor data for enhanced tool control.

Client: The exclusive web interface that facilitates communication between the user and Tzilacatzin, providing real-time status updates and control options through:

- Intuitive user interface for remote operation and monitoring.
- Real-time video feed and sensor data display.
- Secure communication protocols for encrypted data transfer.

The software architecture is designed to be scalable, flexible, and adaptable to various mission requirements, ensuring Tzilacatzin can efficiently and effectively perform a wide range of underwater tasks.

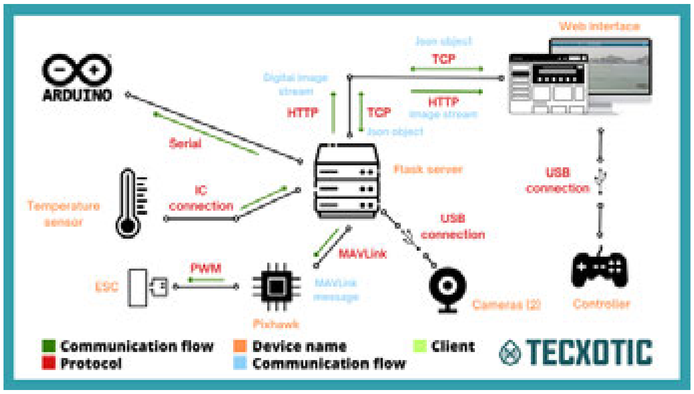

Fig. 20 “Architecture diagram”

C. Interface

This year, the team reused and enhanced the second interface designed for copilot usage to address the challenges of this season. This interface facilitates task execution and ensures their successful completion, aiming to streamline and improve overall operational efficiency. This addition not only enhances the copilot's experience but also improves the pilot's interface by providing better visibility through the use of cameras.

Due to their functionality and efficiency, both interfaces are organized into the following main sections:

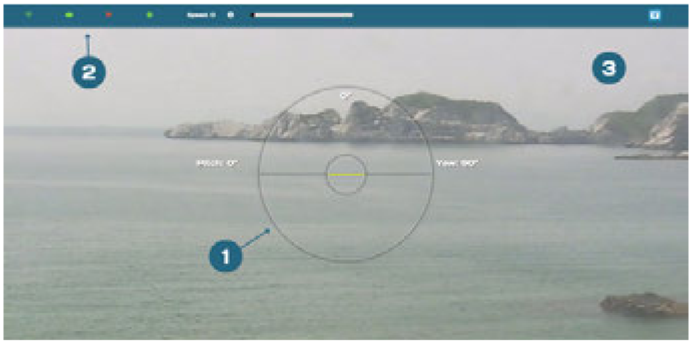

Fig. 21 “Main Interface”

1. Gyroscope: A dynamic device that adjusts its position based on the movement of Tzilacatzin.
2. Status Indicators and Control Center: This section includes various displays showing relevant information about Tzilacatzin's status and offers options to control its movement, such as speed adjustments.

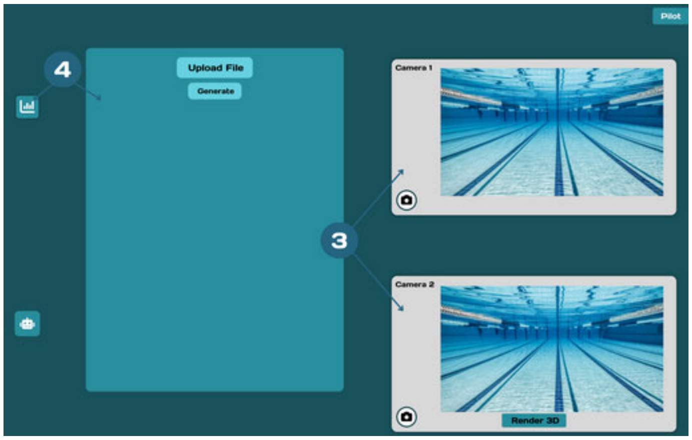

Fig. 22 “Copilot Interface”

3. Video Display: Provides a real-time video stream from the digital webcams, giving both the pilot and co-pilot an up-to-date view of the ROV's surroundings.

4. Task Modules: Features a functional interface for each specific task, allowing for efficient, organized, and intuitive execution of different tasks.

As with last year, the team selected the NVIDIA Jetson Nano board as the main processor due to its exceptional image processing capabilities. Leveraging its high-speed performance, real-time video streams are delivered seamlessly to both the pilot and copilot interfaces, thanks to the efficient combination of CUDA threading and OpenCV builds.

D. Communication Flow Chart

The NVIDIA Jetson Nano, the brain of C, runs on Ubuntu 20.04 LTS and JetPack V4.6, a robust operating system optimized for AI and robotics applications. To keep things running smoothly, we've got a single server that takes care of both movement and video transmission for Tzilacatzin with distinct responsibilities:

Vision and Motion Control Server

- Runs on Flask, a lightweight and flexible web framework, to maintain constant communication with the ROV's sensors, motion control systems, and tools.
- Handles real-time sensor data processing, motion control algorithms, and tool actuation.
- Enables low-latency communication with the surface control station, ensuring precise control and monitoring.
- Utilizes a REST API.
- Employs a TCP.
- Manages computer vision algorithms, object detection, and tracking, as well as autonomous decision-making processes.

This setup allows for the integration of sensor and vision processing, leading to efficient system performance. It's like having a well-oiled machine where all parts work together seamlessly. It also enhances security through standardized data transmission protocols and provides scalability and flexibility for future upgrades and feature additions.

By leveraging this sophisticated communication flow chart, Tzilacatzin ensures seamless data exchange, efficient processing, and reliable control, making it an ideal solution for complex underwater operations.

9. Tools Overview

Tzilacatzin has achieved a significant milestone this year by designing a brand new, unique tool capable of accomplishing all tasks specified in the RFP requirements.

A. 360° Claw

A single multi-purpose gripper is positioned on the ROV's front tool deck. The components of this gripper were 3D-printed using PETG, enhancing its durability and precision. The tool achieves a degree of freedom through the use of a high-torque servo motor, powered by a 12.0 V DC source, enabling it to rotate the full claw 360° in both directions. This provides comprehensive maneuverability, a new form of movement that has not been explored in TecXotic's history until now. Additionally, a second motor utilizes a spur gear mechanism to open and close the gripper, ensuring exceptional precision and control in operation.

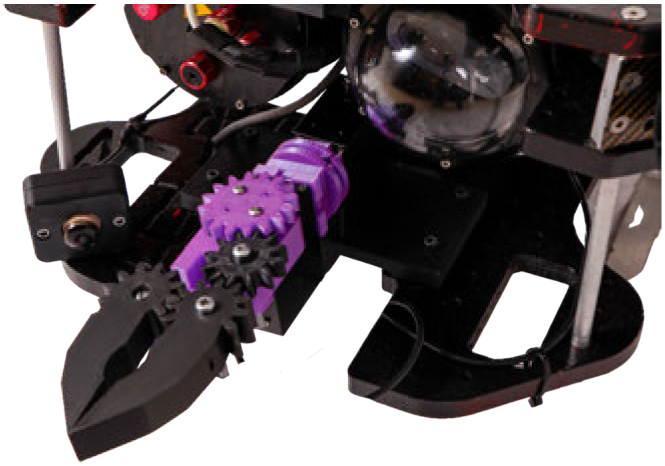

Fig. 23 "Main Tool Claw"

10. Non-ROV Device

A. Design and Bouyancy Engine

Compared to last year, TecXotic's float device has been improved by adding two baumanometers, enhancing our ability to control buoyancy more precisely. The buoyancy engine uses a membrane that inflates and deflates, adjusting the float's volume and density to control ascent and descent.

Fig. 24 "Non-ROV Device Design"

B. Electronics and Control

Inside the cylinder, the system includes an air pump, a solenoid valve, and two baumanometers working together to manipulate a pressure bag. A Blue Robotics Bar30 Depth sensor, along with a gyroscope and accelerometer, provide precise epth control. It regulates the pump based on sensor readings and functions as an access point to the pilot and copilot web page for the ground station to connect, obtain telemetry, and start the immersion process.

By incorporating dual baumanometers, we have achieved a more stable and responsive float performance, significantly improving the effectiveness of our non-ROV device for various underwater missions.

11. Testing and Troubleshooting

The initial stage of testing involves digital simulations, aimed at minimizing time and material waste during prototyping. Once the design has met the objectives of the Sustainable Manufacturing Workflow (SMW) philosophy, it is manufactured using appropriate technologies. Additive manufacturing is used for producing the ROV's tools, while a CNC router is employed for creating larger parts or components that serve a structural purpose. Tests are conducted to verify three critical aspects of the tools: durability, reliability, and repeatability. Durability tests assess the tools' robustness and longevity under operational conditions. Reliability tests ensure consistent and effective performance of the tools across multiple tests. Repeatability tests confirm that the tools perform their functions accurately and consistently in repeated uses. These stages ensure that the ROV's tools, such as the WASP system and the sample collector, meet the necessary standards for practical application, including the safe transport of live fish and the conduct of environmental studies.

12. Conclusions

A. Results

Tzilacatzin embodies the accumulation of countless past experiences, dedicated effort, ime, and passion from every member of TecXotic. It captures the aspirations of numerous students who have toiled within the walls of the MakerSpace, now realized in an ROV. Every error, every lesson learned, every moment of laughter and tears, every mentor's advice has led to this point. TecXotic is poised to elevate Tzilacatzin to the heights it deserves.

B. Challenges

The main challenges TecXotic faced this year were primarily related to redesigning certain components of the ROV to meet this season's demands and to drive innovation. Additionally, another significant challenge was that the majority of the team members were new, necessitating a period for them to familiarize themselves with the work at TecXotic and the competition guidelines. However, thanks to the passion, dedication, and perseverance of both new and experienced collaborators at TecXotic, who strive to keep the project alive, the workflow, protocols, and the characteristic enthusiasm of the company were successfully maintained.

C. Future Improvements

TecXotic has always been driven by a relentless pursuit of improvement and innovation across various domains. The company takes pride in its philosophy, which has enabled it to build on the knowledge gained from each competition. Equally important is the effective transfer of this knowledge to future generations. Therefore, TecXotic will concentrate its efforts on developing comprehensive guidelines for each work area and establishing best practices to minimize the waste of both human and material resources.

D. Lessons Learned and Skills Gained

TecXotic isn't just a team; it's a community of individuals driven by a shared vision: to push the boundaries of technological innovation and delve into the mysteries beneath the waves. The MATE ROV Competition acts as a catalyst, igniting the creativity and problem-solving skills of TecXotic's members. From crafting underwater robots to maneuvering through complex tasks, the competition presents a myriad of challenges demanding technical prowess and strategic acumen. Team members are encouraged to think innovatively, constantly refining their designs to surmount obstacles. Yet, the impact of the MATE ROV Competition extends beyond technicalities. It reshapes the lives of participants, fueling their aspirations and teaching invaluable lessons in teamwork, leadership, and perseverance. They come to understand the collaborative essence of scientific pursuits, realizing that genuine innovation thrives on collective effort. As TecXotic embarks on its journey in the MATE ROV Competition, it inspires others to dream boldly and embrace the transformative potential of collaboration, innovation, and exploration. Their narrative stands as a testament to the profound influence of pursuing one's passions and the enduring legacy of platforms like the MATE ROV Competition in shaping the aspirations of future generations.

13. Acknowledgments

Our Alma Mater, Tecnológico de Monterrey, Campus Cuernavaca, for its generous funding, working facilities, and unwavering commitment to education.

MATE Center and Marine Technology Society

For sponsoring the 2024 International Competition and inspiring us to create “The ocean we need, for the future we want.”

TecXotic Mentors

David García, MBA

For always believing in us, inspiring us daily, and showing us that passion for our work is the ultimate goal in life.

Jesús Simental, Ph.D

For your unconditional support and enjoyable evenings. Most importantly, for demonstrating the importance of loving what you do.

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Alfredo Nava, B.A.
Advanced Manufacturing Lab Coordinator
Antonio Flores, Mr.
Campus Security Coordinator
Ignacio Merlín, B.A.
Maker Space Coordinator (TecXotic HQ)
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Director of the School of Engineering and Science
José Moya, MBA
General Director
Ricardo Valera, MSc
Electronics Professor
Salvador Fuentes, Mr.
Applied Engineering Center Coordinator
Sergio Hernández, MSc
Computer Science Professor
Tecnológico de Monterrey, South & Central Region
Jorge Reyes, Ph.D.
Director of the Mechatronics Department, South & Center Region.
Julio Noriega, Ph.D.
Dean of the School of Engineering and Science, South & Center Region.
Tecnológico de Monterrey
Feniosky Peña-Mora Ph.D.
Dean of the School of Engineering and Science.
Juan Pablo Murra, Ph.D - Rector of professional and graduate.
Our Sponsors
For believing in the power of education and passion as the future of our country, and especially for helping this group of passionate thinkers achieve their dreams.

WÜRTH

makermike.io.16.com

14. References

- Leonardo, B. (2023). *Caracterización del polialuminio a partir del reciclaje de envases de tetra pak*. Revista Vía Innova, 10(1), 13-23. https://dialnet.unirioja.es/descarga/articulo/8740112.pdf
- Su, Y., De Mercado, O., Contribuir, P., Impacto, A., & Ambiente, D. (n.d.). CANINTRE-CANACINTRA CANACINTRA. Retrieved May 21, 2024, from https://www.canacintraens.org/wp-content/uploads/2021/01/polialuminio.pdf
- Hawaii Public Radio (2019). *Corals Are Adapting to Higher Temperatures, But Likely Not Fast Enough*. https://www.hawaiipublicradio.org/local-news/2019-10-24/corals-are-adapting-to-higher-temperatures-but-likely-not-fast-enough#stream/0

Appendant 1

CRITERIA	ATZIN 2.0	TZILACATZIN	GOAL	RESULT	GA
Overall Width	0.58 m	0.68 m	▽	▲	**NA**
Overall Length	0.59 m	0.63 m	▽	▽	**A**
Overall Height	0.35 m	0.33 m	▽	▽	**A**
Envelope Volume	0.13 m3	0.13 m3	-	-	**NC**
Free Space Volume	850 cm3	850 cm3	-	-	**NC**
Tether length	20 m	20 m	-	-	**NC**
ROV Mass	14.2 kg	17.74 kg	▽	▲	**NA**
Tether Mass	3.2 kg	3.2 kg	-	-	**NC**
# Modular Floats	6	0	▽	▽	**A**
# ROV Parts	173	171	▽	▽	**A**
# ROV Tools	3	1	▽	▽	**NC**
# Diff. nuts & bolts	6	6	-	▲	**NA**
# Diff. Actuators	1	2	▽	▽	**A**
Horizontal Thrust	58.8 N	58.8 N	-	-	**NC**
Vertical Thrust	58.8 N	58.8 N	-	-	**NC**
Horizontal Speed	0.76 m/s	0.75 m/s	▲	▲	**A**
Vertical Speed	0.62 m/s	0.62 m/s	▲	▲	**A**
Degrees of Freedom	4	1	-	-	**NC**
Power Consumption	223.6 W	250.56 W	-	-	**NC**

GA = Grade of Achievement
A = Achieved **NA**= Not Achieved **NC** = No Change

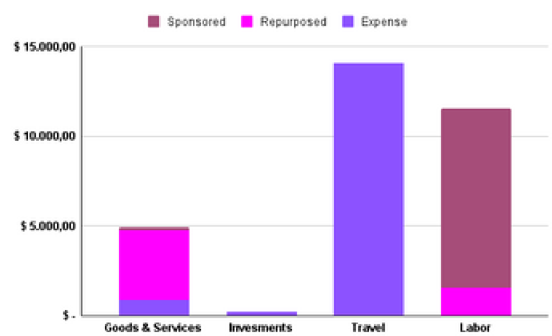
Appendant 2

GOODS & SERVICES

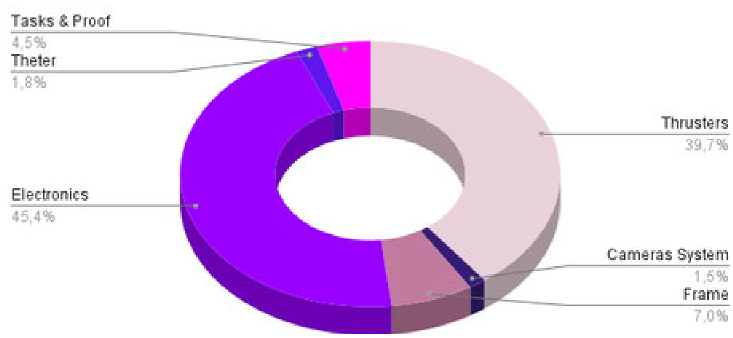
Part Name	Description	Expense	Repurposed	Sponsored
Thruster / Motors Expenses				
Thrusters	T200 Thruster	$ 235,00	$ 1.400,00	--
Basic ESC	A simple electronic speed controller for the T100 and T200 Thrusters.	$ 36,00	--	--
Thurster guards	3D printed guards	$ 25,00	--	--
Servos	50Kg IP65 Geared servo Motor (2)			$ 200,00
Cameras System Expenses				
Part Name	Description	Expense	Repurposed	Sponsored
	Angular camera (4)	$ 70,00	--	--
Frame Expenses				
Part Name	Description	Expense	Repurposed	Sponsored
Frame	Composite aluminum panel	--	--	$ 86,50
Upper frame plate	PolyAl panel	--	--	$ 65,00
Tools components	3D printed tool pieces and frame parts	$ 48,00	--	--
Structure	Brass threaded inserts // 8 in. Cable Tie - Natural (100-Pack) // Hot Glue Sticks // 1/4 - 20 lock nuts 100 pieces box	$ 95,00	--	--
Enclosure dome	Dome- optically clear acrylic (4" inner diameter)	$ 40,00	--	--
Electronic Expenses				
Part Name	Description	Expense	Repurposed	Sponsored
Sensor & Controls/ Controller	Bar30 High-Resolution 300m Depth/Pressure Sensor // CUAV Pixhawk PX4 Flight Controller // Flat TV 32"	--	$ 434,60	--
Water Enclousure	Acrylic Tube // Dome end CAP // Aluminum End Cap with 10 Holes (4" Series) // Cable penetrator for 6 mm // Cable penetrator for 8 mm // Cable Penetrator Blank (No Hole)	--	$ 223,00	--
	Epoxy resin & catalyzer // Loctite Marine Epoxy // 10x Potted Cable Penetrator // O-Ring set // Epoxy resin (transparent) 1.5 kg	$ 92,90	--	--
Voltage converter	Dc-dc Buck Converter Adjustable to 15a 200w 8-60v input (6 pieces) // Control voltage regulator DC 6-40 V	--	$ 57,00	--
Voltage converter	450-PQC75-48-S12-OH Isolated DC/DC Converter	$ 97,00		
Actuadors	10 watts led, sumersible pump, 4x 9v geared motor	$ 41,00	--	--
Tether, cable and wire	Turnigy Pure-Silicone Wire (blue & red) // THWN WIRE (2 x 12 AWG) // UTP CAT6 WIRE // Ethernet Cable // USB Cable 90 Degree Right Angle	--	$ 279,97	--
Input device	Dualshock playstation 4	--	$ 66,70	--
FUSE	58V 40 A FUSE HOLDER // 30A 58V FUSE	$ 11,86	--	--
Connectors and joins	Thermofit 1/8" - 1/2"// Anderson SBS50 Heavy Duty Power Connector // Thermofit multi-size (850 pieces) // Solder connector (50 pieces) // (5 & 3) Pin PCT213 (20 pieces) // Double sided adhesive	$ 118,55	--	--
Electronical Components	Nvidia Jetson nano // Logitech webcam // 7 Port Hub USB // Humidity control envelopes (100 pieces)	--	$ 746,00	--
Tether				
Part Name	Description	Expense	Repurposed	Sponsored
sleeve	Tether Nylon Sleeve	--	$ 57,20	--
ethernet cable	CAT-6 RJ45 ethernet cable	--	$ 13,00	--
Anderson connector	Anderson Power Connector (To main point of connection)	--	$ 6,00	--
USB cable	1m male to male USB A extension cable	$ 12,00	--	--
Tasks & Proof Expenses				
Part Name	Description	Expense	Repurposed	Sponsored
Product demostrations	1/2-inch PVC pipe // 1/2-inch end cap// 1/2-inch tees// 1/2-inch 90 and 45 elbows// 1/2-inch coupling// Paired wires // 1/2-inch tees // 18 gauge red black wire //Colored duct tape // Industrial strength Velcro (white)// 2 gallon bucket // 1x soft bottle // LEDs // plastic test tube // Orange, blue, green, yellow spray paint	--	$ 144,40	--
Product demostrations	3/4-inch PVC male and female adapter // 1 inch PVC pipe// 1 inch PVC end-cap// 1/2-inch sideouts// 1 to 1/2-inch reducing tee// 1 to 1/2-inch reducer bushing// 4 inch PVC pipe//4 inch PVC knockout caps// rope // 3 inch carabiner //2 inch knockout cap// Large plastic bowl // 2 inch PVC coupling // 2 inch PVC end cap // Industrial strength Velcro (white)// 2 gallon bucket // Photoresistor// corrugated plastic sheet //pipe cleaner// fish fry // red, black spray paint	$ 71,20	--	--

	Type	Part Name	Expense
INVESTMENT	**Machinery & Tooling**		
	Machinery	Lathe cooling system	$ 60,00
	Tools	Cutters & drills	$ 30,00
	Tools	Crimpers	$ 25,00
	Tools	Wrenchs	$ 130,25
TRAVEL	**Travel Cost (12 people)**		
	Travel costs	Mentor travel costs	$ 1.200,00
	Travel costs	Accomodation	$ 3.000,00
	Travel costs	Ground transportation	$ 1.500,00
	Travel costs	Plane tickets	$ 3.600,00
	Travel costs	Travel insurance	$ 800,00
	Travel costs	Food	$ 4.000,00
LABOR	**Labor Cost**		
	Type	Part Name	Expense
	Uniforms for 25 people		$ 1.250,00
	Personal protection equipment		$ 350,00
	Design & manufacturing labor		$ 10.000,00

	Expense	Repurposed	Sponsored	
Goods & Services	$ 896,51	$ 3.885,86	$ 151,50	$ 4.933,87
Invesments	$ 245,25			$ 245,25
Travel	$ 14.100,00			$ 14.100,00
Labor		$ 1.600,00	$ 10.000,00	$ 11.600,00
	$ 15.241,76	$ 5.485,86	$ 10.151,50	$ 30.879,12

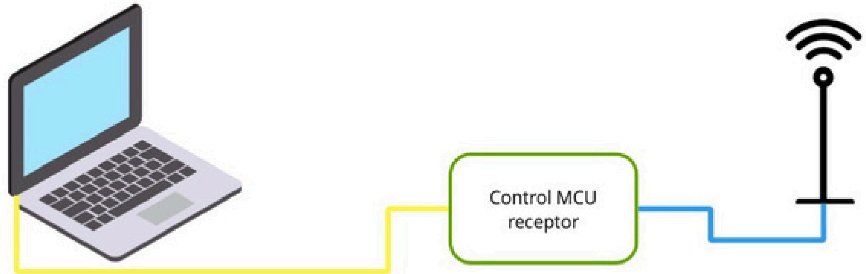


ROV TOTAL COST $ 4772.88



Appendant 3

ABOVE WATER



WATER LINE

Legend

- 9V
- Gnd
- Coaxial
- D0 (compressor 1)
- D1 (compressor 2)
- D2 (contact sensor)
- D3 (buoyancy sensor)
- D4 (Sensor Box)
- D5 (Sensor Box)
- USB
- 3.3V
- D6 (RGB)

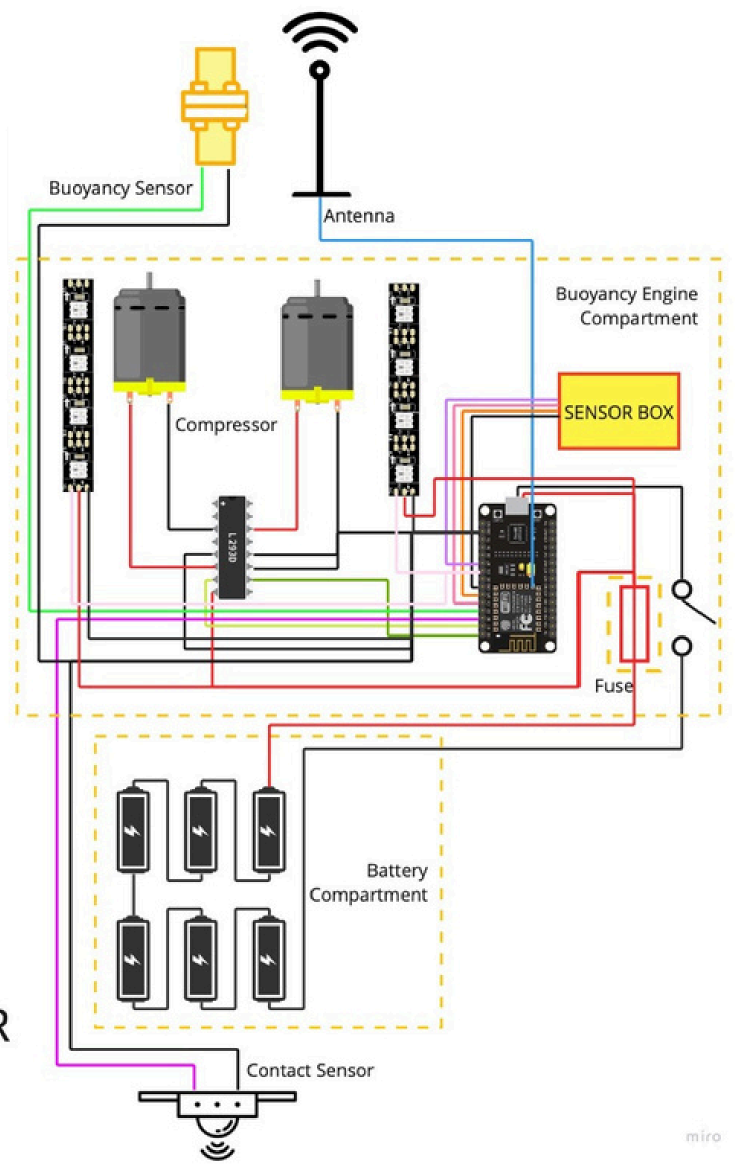
Fuse Calculation

Peak Current: 3.35A

With the safety factor (ELEC-008E), it gives a fuse value of:

3.35A x 1.5 = 5.025A

We selected a 5A fuse.



UNDER WATER