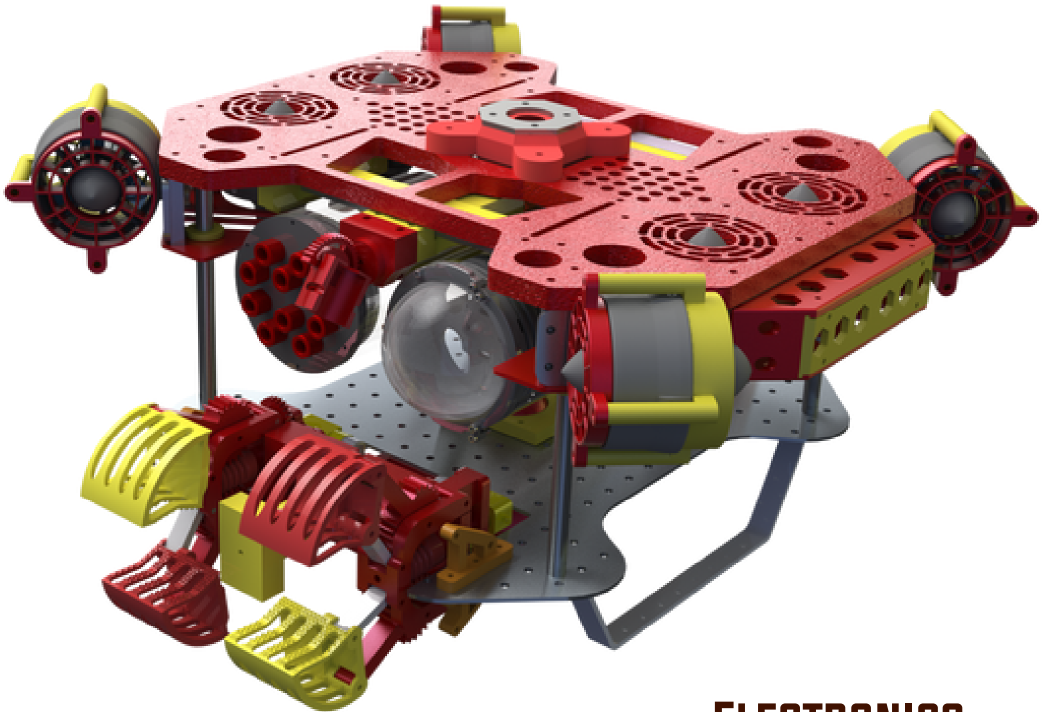
TECXOTIC

TECHNICAL REPORT 2023

Xochitepec, Morelos
México



MENTORS

David García | MBA
Jesús E. Simental | PhD
Javier Montiel | M. Ed
J. Miguel Pérez | BSc

CEO
Julio Fragoso | 8th

SO
Jorge Turner | 6th

COO
Baldo Ávila | 6th

FINANCE

CFO
Bernardo Salgado | 6th

DESIGN

CDO
Osmar Rico | 6th
Regina Blas | 8th
Laura Santos | 6th
Julio Fragoso | 8th
Jorge Álvarez | 2nd
Pablo Gutiérrez | 4th
Eduardo Godoy | 2nd
Priscila Jinsil Kim |6th

SOFTWARE

CIO
Marco Gardida | 6th
Dulce Bucio | 4th
Jorge Turner | 6th
Leonardo Pérez | 8th
Miguel Jiménez | 6th
Antonio Nogueron | 4th
Armando Arredondo | 4th

ELECTRONICS

CTO
Pablo Gutiérrez | 4th

CCO
Alejandro Hidalgo | 6th
Ariel Calderón | 6th
Daniel Hidalgo | 4th

STEM

CSEO
Mariana De la Rosa | 6th
Leslie Flores | 2nd
Iker Landeros | 4th

Tecnológico de Monterrey

HECHO EN MEXICO

TABLE OF CONTENTS

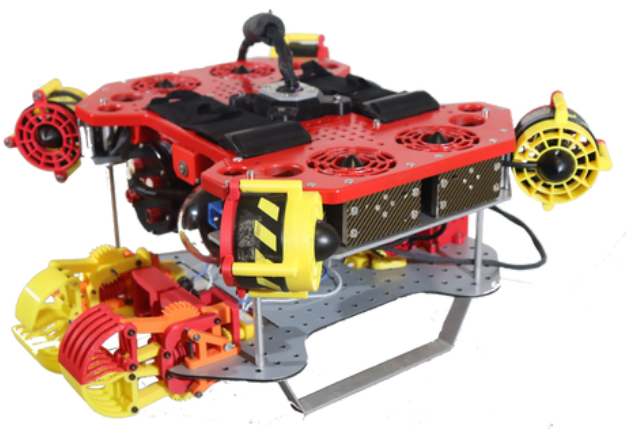


Fig. 1 & 2 "ROV"

Fig. 3 "CCU"

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

Software:
- Frontend: Web interface.
- 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

Control Box:
- GCU: Ground-Control Unit

1.ABSTRACT

In recent decades, the escalating issues concerning oceans, rivers, and lakes have garnered significant attention from organizations such as the UN and various governments. In response, ROVs have emerged as a dependable solution, carrying out crucial tasks associated with renewable energies, conservation of Blue Carbon, marine health supervision, among others.

With a steadfast commitment to environmental concerns and upholding stringent safety and quality standards, TecXotic was founded eight years ago. This year’s efforts culminated in the development of Atzin 2.0, the company's latest ROV. Designed to address a wide array of underwater challenges, Atzin 2.0 embodies sustainability, embracing innovative approaches like the use of recycled materials and minimization of disposable components.

Consequently, Atzin, last year’s ROV, served as the foundational platform to establish a work model that directly addressed the areas of opportunity identified in the previous year, not only pertaining to the ROV but also within the organization itself, capitalizing on the experience and knowledge gained from each past season. A pivotal aspect of this transformation was the restructuring of the company from a traditional pyramidal model to a horizontal structure centered around connectivity and participation. This empowered every team member to contribute ideas and insights at any given moment and focus on leaving documented and established processes for future generations.

This report endeavors to provide the reader with comprehensive insights into TecXotic's design, manufacturing, and software development processes throughout the creation of Atzin 2.0, as well as Corporate Responsibility endeavors done throughout the year.

WHO CARES, ALWAYS WIN

Fig. 4 "TecXotic 2023"

2. SAFETY

A. SAFETY RATIONALE

TecXotic is committed to create the best possible work environment that encompasses collaborators, potential customers, and the environment, none less than others. A great level of attention to safety aspects promotes confidence and comfort while working, allowing correct manufacturing, task completions, avoiding unnecessary rework, and mitigating hazards. TecXotic follows international standards and safety regulations. Something that has been present in TecXotic for a while but did not have a name until now is Safety Awareness. Safety Awareness seeks to create a complete ecosystem where all stakeholders are safe and organized, and where everyone ensures each other's safety. Safety Awareness is essential because TecXotic cares, and Who cares, always wins.

Fig. 5 "Safety lab protocols"

B. TRAINING

All collaborators must undergo general training, and depending on their field of work, specialized training. These training programs promote Safety Awareness, reduce accidents, 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. Other specialized training are DeckOps (tether protocol, power up protocol, launch and recovery), safety awareness orientation, and back safety.

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.

C. SAFETY TECXOTIC COLLECTION

TecXotic has curated a collection of documents and handbooks that are revised annually to ensure and comply with Safety Awareness and good practices at all times. A safety handbook is distributed and used in general training for all collaborators. More information regarding safety, protocols, and manufacturing processes can be found in the Standard Operation Procedures (SOP), Job Safety Analysis (JSA), Safety Data Sheets (SDS), and TecXotic's DeckOps Checklist.

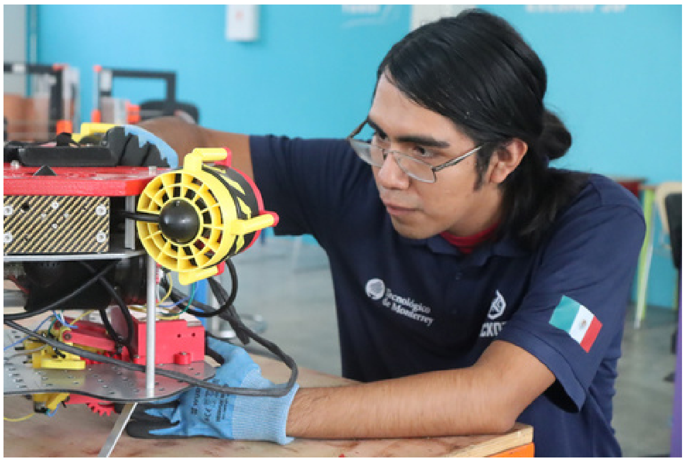


Fig. 6 "Safety lab protocols"

D. SAFETY FEATURES

Atzin 2.0 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.

- ROV: warning stickers are placed in moving components. Sharp edges are considered and removed in the design phase. Thrusters are protected with IP-20-compliant guards. Cables that enter the enclosures go through either BlueRobotics WetLink penetrators or Potted penetrators using marine-grade epoxy resin. All components are IP-68 or IP-69(K) rated. A positive buoyancy allows easier recovery on complete power loss during operation. Fuses in the ROV and non-ROV devices serve as overcurrent protection.

- Software: if the connection is lost with the ROV, the control system will automatically try to reconnect until stopped by the operator. Operators can enable and disable the ROV from the control system.
- Operator: An Emergency Stop Button is ever-present and ready to terminate immediately all power to the ROV.

3.DESIGN RATIONALE

A.DESIGN METHODOLOGY

For the design of TecXotic's 2023 edition ROV, three pillars were kept in mind: sustainability through the SMW philosophy, maintaining everything that functioned in the previous ROV instead of beginning from zero, and a new approach in the company organization.

Taking the base that was Atzin. Atzin 2.0 presents the following design guidelines obtained through a series of evaluations and feedback meetings. After running diverse Failure Mode and Effect Analyses (FMA) for Atzin, 8 design guidelines and recommendations were defined for Atzin2.0:

1.MANTAIN ⚓ Safety practices & protocols.
2.MANTAIN ⚓ Adjustable buoyancy.
3.INCREASE ▲ Frame's rigidity.
4.DECREASE ▼ Assembly complexity.
5.DECREASE ▼ Prototyping time.
6.IMPROVE ⚙ Tool reliability.
7.IMPROVE ⚙ User interface for the copilot.
8.IMPROVE ⚙ Sustainability.

Fig. 7 "Design guidelines"

Appendant 1 - Season accomplishments

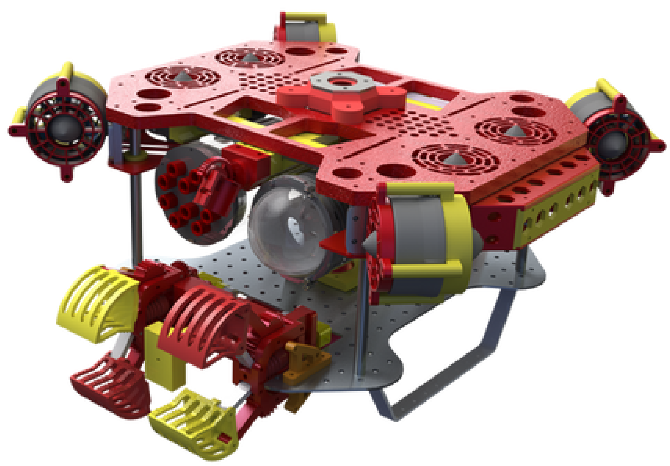


Fig. 8 "Atzin 2.0 isometric view"

B. DESIGN PHILOSOPHY

One of the key components of TecXotic's design philosophy is the SMW (Simple, Modular, and Well-done) methodology; it was implemented in every subsystem to facilitate the assembly with a holistic system approach.

SIMPLE: Designs must be as simple as possible. This reduces weight, manufacturing complexity, and failure. A design with fewer parts has a lower probability of errors, defects and failures.

MODULAR: A modular design provides the capability to make repairs, adjustments, and improvements to designs. Modularity requires the standardization of pieces, components, and assemblies. This also allows us to strategically manufacture spare parts for the competition, minimizing the total amount of equipment the team needs to transport to the competition.

WELL-DONE: It involves a focus on the quality of designs, drawings, specifications (documentation), and manufacturing processes.

Fig. 9 "SMW philosophy"

The other key component relies on lessons learned throughout the years. In the very first ROV of TecXotic the thrusters were handmade and the team suffered from reliability issues on the ROV's movement. The cable management in the second version of the ROV required an immense amount of work to function properly. The geometry and material of the third ROV limited the size and the possible tool positions. The thruster distribution in the fourth and sixth iteration was suboptimal, leaving empty usable spaces to not obstruct the flow of the thrusters. The fifth iteration left a lot of empty space inside the ROV. The seventh version suffered deformation due to lack of structural strength.

All past experiences add up and result in who we are now, and TecXotic is no exception. That is why each of the different versions seeked to improve over the previous one and avoid making the same mistakes. This has led us to follow an ever-growing list of restrictions and recommendations that, although it may seem overwhelming at first, reminds us that creativity arises from limitations and that is what motivates us to keep trying to create the best ROV we can in each edition of the MATE ROV Competition.

4. Project Management

A. Company Organization and Assignments

TecXotic is divided into four main departments: Design, Electronics, Software, and Corporate Responsibility. Each department has a Department Lead, who is in charge of assigning tasks for the area and time limits for each activity, while keeping direct contact with the other areas to develop integrated systems that take into account the whole functionality of the ROV while maintaining a focused workflow. Every department actively participates in the documentation which prevents requiring a dedicated area and mitigates communication mistakes between department developers and third parties. At the start of the season a recruitment campaign was made, attracting nearly 20 new members interested in the different areas of the project.

B. Project Management

Department Leaders hold weekly meetings to check which assignments have been finished in due order and to establish new activities for the week, while sticking to a general

Fig. 10 "TecXotic's 2015-2023 ROV's""

schedule made on a monthly basis. At the start of the season, each department had a "focus" period where most of the team participated in its activities; this was done to help new members approach each area and decide where they would like to participate. After this initial period, the general planning was established, identifying possible risks and/or major bottlenecks. An important statement for this season is that it is the first time that TecXotic works on an ROV based on a previous design. Using Atzin's design as a base allowed the company to focus on improving every aspect of it without having long prototype periods or requiring a completely new platform. This makes Atzin 2.0 the best ROV made by the company so far. After this, work was divided by weeks, focusing on the areas of opportunity detected in Atzin's design, electrical system and software.

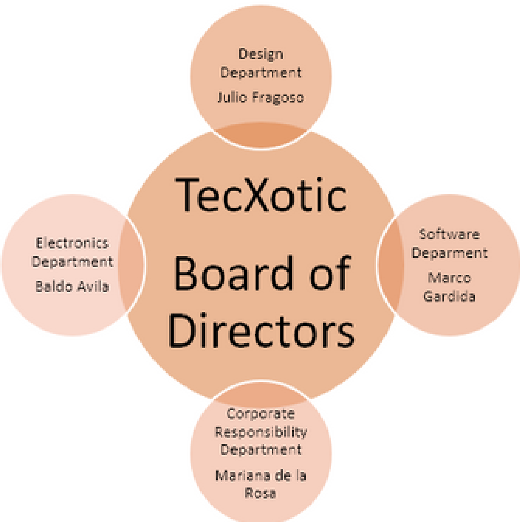


Fig. 11 "Company Organization"

C. WORKFLOW

The workflow was established weekly by the Department Leaders, assigning specific tasks to every team member and delivering specific milestones for each task to be accomplished by the end of the week. In this way, each department had significant and measurable advances each and every week.

D. COLLABORATIVE WORKSPACE

Due to the positive experience achieved during its utilization last season, ClickUp was chosen once again as the main project management tool. ClickUp allows Department Leaders to create new tasks with due dates and specific sub-tasks to be performed by each member, allowing also to keep track of each task and sub-task. Also, in case that the more experienced members have finished their own duties, they can check ClickUp and see which other tasks are unfinished to provide assistance. Also, if any tasks remain unfinished by the end of their assigned period they can be taken into account to be prioritized for the following week without handing more tasks to the assigned collaborators.

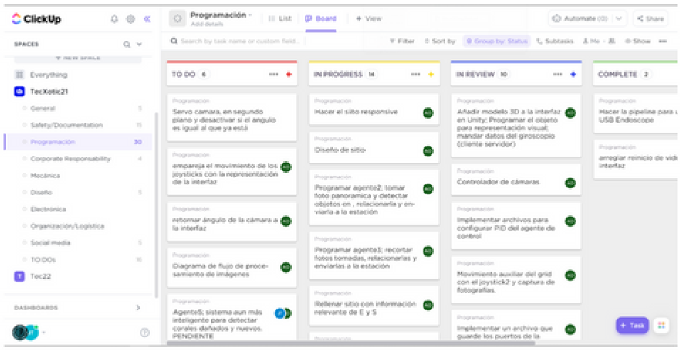


Fig. 12 "Clickup Workspace"

Other collaborative tools used are Zoom for on-line meetings when needed, since it allows screen sharing, facilitating direct sharing of information or helping to solve doubts of other team members when not physically present in the same environment. Finally, the Google suite is used to store the company's Database, which contains information about every season and ROV that has been constructed, and to create collaborative documents, which allow every member to have access and modify them in real time.

E. CODE MANAGEMENT

The company uses GitHub to host the backend and frontend repositories. In addition, good practices and order are used when working, since branches are used to develop code that is later reviewed before being added to the main branch to maintain a clean code that works all the time, avoiding big crashes or problems that would require the whole code to be checked.

5. BUDGET AND COST PLANNING

As the company works under a limited budget, a considerable number of components from previous designs were re-used to decrease ROV's production expenses.
An individual budget was assigned to every department and was closely monitored to make sure all expenses were referred to the Finances Department. The main focus when purchasing new components was to ensure that certain functionality and reliability level was accomplished and that all new parts were related to the tool development. Employee transportation was not considered since these expenses are covered individually.

Appendant 2 - Budget table

6. ELECTRICAL & ELECTRONICS

A. ELECTRICAL OVERVIEW

Atzin 2.0's general electrical system takes the best of past years into a properly distributed, more ordered and accessible design, keeping focus once again in the SMW philosophy. Therefore, the general overview is pretty similar to Atzin's, having three main sections: Above the Waterline (GCU), which allows interaction between operators and the ROV, Below the Waterline (within two electronic enclosures), where all operations like voltage reduction and distribution are made, and the Tether, used only for communication and main power. The electronics disposition inside the enclosures is designed to allow quick identification of any problem sources and easy replacement of components.

Once again, TecXotic has decided to simplify the operation of Atzin 2.0 by not using pneumatics or hydraulics, avoiding fluid lines through the Tether and extra variables (like pressure gauges) that would need to be controlled or monitored by operators in the GCU. On the other hand, an eight thruster layout has been chosen once again to provide the best possible displacement capacity, equal thrust in any direction and high maneuverability despite Atzin 2.0's size, for which eight T200 BlueRobotics® thrusters have been used. Therefore, at top performance Atzin 2.0 has an average current consumption of 14.08 A.

B. ABOVE WATERLINE ELECTRONICS - GROUND CONTROL UNIT (GCU)

The GCU is the main station where operators interact with Atzin 2.0 and the software interface. Several displays are used to showcase all the information provided by these two elements, those being: two digital cameras connected to the main on-board processing unit (NVIDIA Jetson Nano) used for software and image processing tasks, as well as four analog cameras for the operation of the ROV and the interface used to input and extract data to and from the main software. Safety was a priority during the design and manufacturing of the GCU, since it's the element with the most human interaction during the usage of the ROV. Hence, it counts with several safety measures such as an emergency stop button, which immediately interrupts the 48.0 V power supply and a Littlefuse 25.0 A fuse within 30.0 cm from the main power supply input (for fuse calculations please refer to SID).

Fig. 13 "GCU"

C. Waterline Transition

The Tether is the only connection between the GCU and Atzin 2.0, connecting with the ROV through TecXotic's proprietary tensor relief mechanism, which allows minimal to zero strain on the cables and allows all tension to be absorbed by the frame. It is 20.0 m long and carries only four connection lines: two CAT6 ethernet connections for the processing unit and analog cameras and two AWG 14 cables for power delivery (live and ground), covered with an expandable braided sleeve which reduces entanglement, protects the cables and allows easy handling. Having the least amount of cables and adding floats distributed throughout the length of the tether reduces drag and facilitates tether management during the mission.

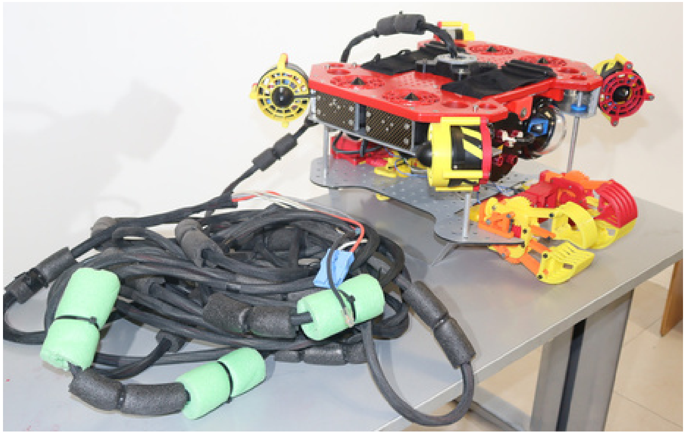


Fig. 14 "Tether"

D. Below Waterline Electronics

The on-board electrical system is contained within two electronic enclosures, each being responsible for different tasks: the TCE contains components for power management and thruster control, while the MCE contains computer processing, image recognition and tool control equipment. This distribution helps to isolate problems related with power supply from direct component problems related from the processing unit, tools, cameras or thrusters. Anderson Powerpole connectors are used for the connections inside both enclosures due to their reliability and maximum current flow capacity. Cables from the Tether, thrusters and communication between enclosures use BlueRobotics® cable penetrators or BlueRobotics® WetLink penetrators whenever possible.

Fig. 15 "Penetrators"

E. Thruster Control Enclosure

The main power supply is delivered from the Tether into the TCE. The voltage input is distributed to the five 200.0 W voltage regulators equipped inside the TCE, all connected in parallel. Four of these regulators convert the voltage from 48.0 V to 16.0 V for the thrusters, controlled through BlueRobotics® standard ESCs. Each regulator provides electricity to two thrusters arranged in a configuration that reduces current consumption and evens out the stress a regulator is subjected to. The fifth regulator outputs 12.0 V, and it provides power to the MCE. The ESCs receive PWM signals to control the thrusters from a Pixhawk 4.

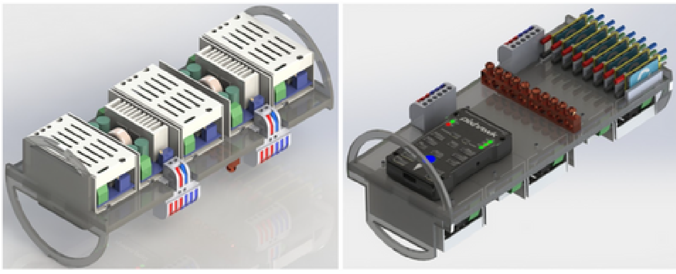


Fig. 16 "TCE"

F. MAIN CONTROL ENCLOSURE

Power running at 12.0 V is received from the TCE and distributed to the different components in this enclosure. In the first place, it is used to power two H-bridges at 12.0 V that control the tools and a lamp. Then, a 12.0 V to 5.0 V Step-Down Module is used to power the main processing unit, an NVIDIA Jetson Nano and an Arduino Nano. The Jetson Nano manages communication with the GCU, the digital cameras, supplies power and data to the Pixhawk 4 and also processes the controller's inputs to control the tools, which then is transmitted to the Arduino Nano through serial communication. Finally, a 12.0 V to 3.3 V Step-Down Module is used to power the four analog cameras pilots use for better vision when controlling the ROV. Step-Down Modules are used not only to reach the component required voltages but also as a safety measure, since they can stop events like current peaks from reaching other sensible components such as the Jetson Nano, while the Arduino Nano is used for a similar reason, avoiding direct connection between the Jetson and the tools.

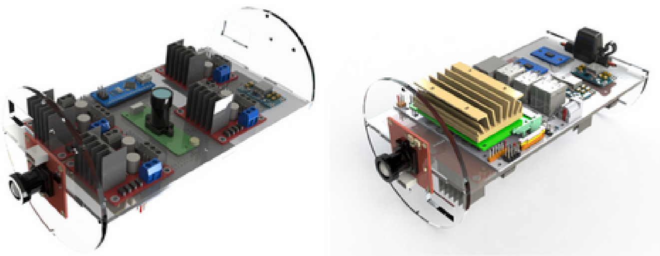


Fig. 17 "MCE"

POWER BUDGET					
SUBCOMPONENT	QTY	VOLTS (V)	CURRENT (A)	TOTAL CURRENT (A)	TOTAL POWER (W)
DC-DC CONVERTER 48 TO 16V 200W EFFICIENCY 94%					
T200-THRUSTER-R2-RP WITH ESC	2	16.00	1.70	3.40	54.40
DC-DC CONVERTER 48 TO 16V 200W EFFICIENCY 94%					
T200-THRUSTER-R2-RP WITH ESC	2	16.00	1.70	3.40	54.40
DC-DC CONVERTER 48 TO 16V 200W EFFICIENCY 94%					
T200-THRUSTER-R2-RP WITH ESC	2	16.00	1.70	3.40	54.40
DC-DC CONVERTER 48 TO 16V 200W EFFICIENCY 94%					
T200-THRUSTER-R2-RP WITH ESC	2	16.00	1.70	3.40	54.40
DC-DC CONVERTER 48 TO 12V 200W EFFICIENCY 94%					
DC GEARED MOTOR WITH H BRIDGE	2	12.00	0.06	0.12	1.44
DC-DC CONVERTER 12 TO 5V EFFICIENCY 94% 15A MAX					
JETSON NANO	1	5.00	0.11	0.11	0.55
PIXHAWK 4	1	5.00	0.15	0.15	0.75
GY-6550 ACCELEROMETER	1	5.00	0.00	0.00	0.00
WEB CAMERA LOGITECH C505	1	5.00	0.03	0.03	0.15
PRESSURE SENSOR	1	5.00	0.01	0.01	0.06
DC-DC CONVERTER 12 TO 5V EFFICIENCY 94%					
ARDUINO NANO	1	5.00	0.02	0.02	0.1
DC-DC CONVERTER 12 TO 3.3V EFFICIENCY 94%					
ANALOG CAMERA	4	3.30	0.01	0.04	0.13
WHOLE ROV SYSTEM*				14.08	220.78
WITH SECURITY FACTOR OF 1.50				21.12	
*THIS ONLY INCLUDES DC DEVICES					
TOTAL CALCULATED CURRENT CONSUMPTION IS 21.12 A; THEREFORE, A 25 A FUSE IS USED.					

Fig 18 "Power Budget"

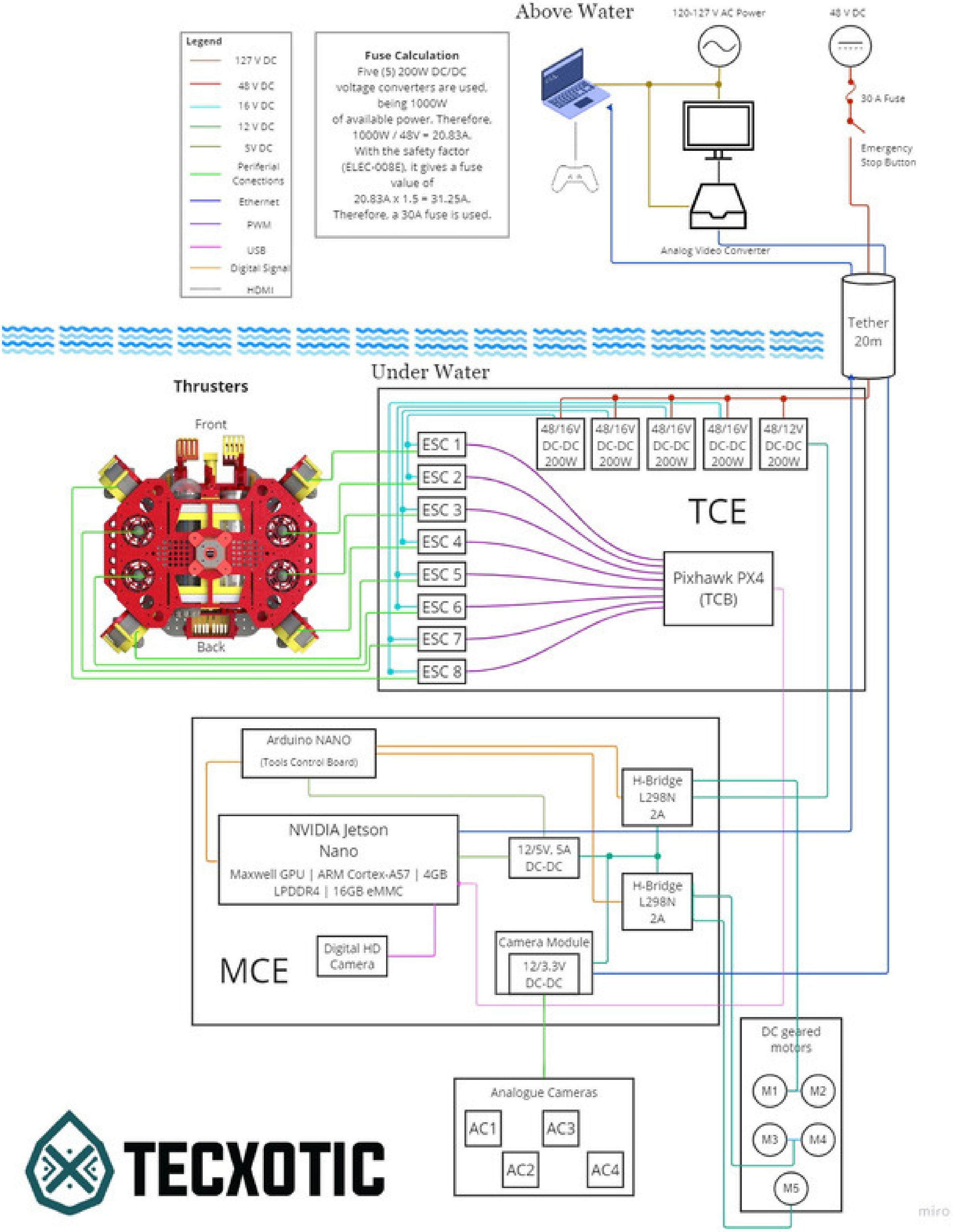


Fig. 19 “ROV's SID”

7. SOFTWARE

A. PHILOSOPHY AND OVERVIEW

Last year, TecXotic's software aimed to develop a cost-effective and easy to maintain system that could be reused and that facilitated the implementation of improvements based on new requirements. Based on the accomplishments and shortcomings of this system, the team has made significant developments and enhancements to address the upcoming needs that we encountered during this season.

B. DESIGN AND SOFTWARE ARCHITECTURE:

While its architecture is the same as last year due to its effectiveness in the control of the ROV and the connection with the client, it is important to present its components and functionalities:

Core: Atzin 2.0's primary control module responsible for managing motion, sensor data and communication with the surface.

Vision and Autonomy: This module is responsible for handling all image processing tasks and implementing the logic for autonomous driving.

Tooling Handler: A fundamental submodule that oversees the control of tools and actuators.

Client: The exclusive web interface that facilitates communication between the user and Atzin 2.0, providing real-time status updates and control options.

C. INTERFACE

This year, the team innovated by implementing a second interface specifically designed for copilot usage facilitating task execution and ensuring the successful completion of them, this way the team aims to streamline and enhance overall operational efficiency.

This addition not only improves the co-pilot's experience but also enhances the pilot's interface by providing improved visibility through the use of the cameras.

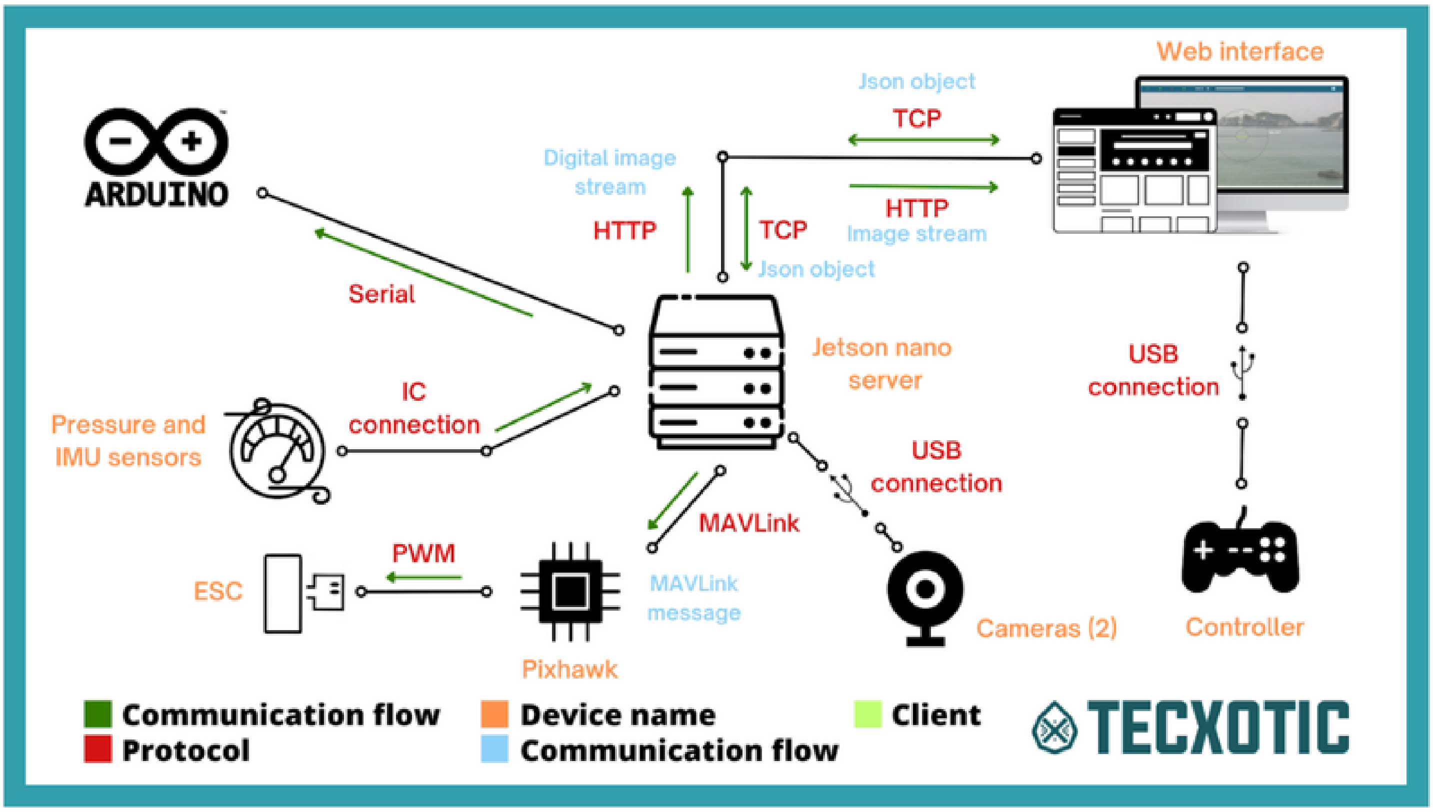


Fig. 20 "Architecture diagram"

For its functionality and efficiency, both interfaces are structured into the following main sections:

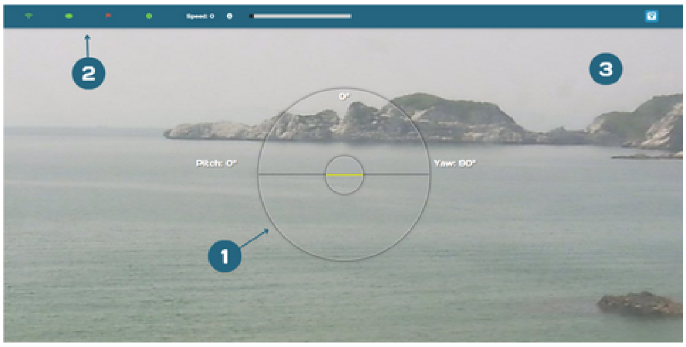


Fig. 21 "Main interface"

1. Gyroscope: It is a dynamic device that adjusts its position based on the movement of Atzin 2.0.
2. Status Indicators and Control Center: They consist of a range of displays that showcase relevant information about Atzin 2.0's status. It also offers options to manipulate its movement, such as adjusting the speed.

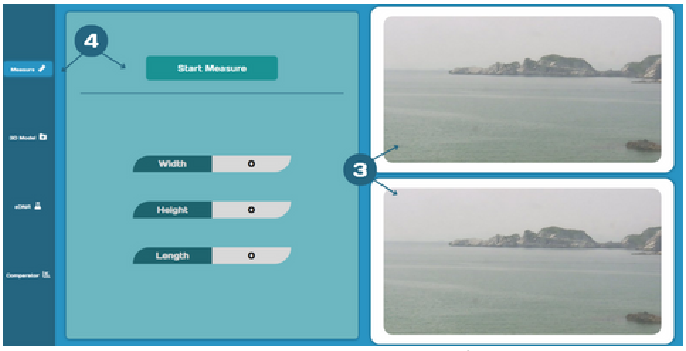


Fig. 22 "Co-pilot interface"

3. Video Display: It provides a real-time video stream from the digital webcams, offering both the pilot and the co-pilot an up-to-date view of the ROV surroundings.
4. Task modules: This feature provides a functional interface for each specific task provided. For example, it includes modules for eDNA reef fish analysis and seagrass monitoring, allowing an efficient, ordered, and intuitive execution of every different task.

Just like last year, the team chose the NVIDIA Jetson Nano board as the main processor for its exceptional image processing capabilities. Leveraging its high-speed performance, it is possible to deliver real-time video streams to both the pilot and copilot interfaces seamlessly, all thanks to the efficient combination of CUDA Threading and OpenCV builds.

D. COMMUNICATION FLOW CHART

The NVIDIA Jetson Nano runs Ubuntu 20.04 LTS and JetPack V4.6 as its operating system. Two servers are run in parallel, one is responsible for sensors, motion control and Atzin 2.0 tools with a WebSocket server to maintain constant communication while the other is in charge of handling vision modules and tasks with a REST API using TCP to secure and protect data transmission between devices.

E. SOFTWARE TOOLING

OpenCV: It is a highly regarded open-source software library for computer vision. It provides extensive capabilities for processing the images captured from two digital cameras and is also utilized in task 2.4. With its comprehensive functionality, OpenCV enables efficient image processing and analysis.

Flask: It is a Python framework specifically designed for web applications. It serves as a bridge between the frontend and backend, facilitating seamless communication and data exchange.

React: It is a Javascript library designed to create user interfaces. It allows modular and flexible designs in addition to offering excellent performance.

MeshRoom: Is an open source software based on the AliceVision Photogrammetric Computer vision framework. Its main functionality relies on constructing a 3D digital structure through a set of photos of the same object, taken from different angles. This software will serve the company for task 2.1, In which a coral will be 3D modeled with its approximate dimensions

Standards followed: For a better understanding and collaborative work, coding standards and nomenclature were implemented. For example, every function or component in code follows the UpperCamelCase writing.

8. MECHANICS

A. MECHANICAL OVERVIEW

Additive manufacturing continues to be one of the main technologies required for the construction of the ROV, since it allows complex geometries and adequate geometric tolerances to be achieved at a much lower cost than other manufacturing technologies. This year's innovation is the use of FDM-type printers with "COREXY" technology, which considerably reduces prototyping times and allows several iterations of the same design to be completed in hours instead of days as in previous years.

Also safety continues to be TecXotic´s top priority. Safety design protocols and operations were followed to ensure all aspects of the vehicle to meet the safety standards stated by the RFP.

B. FRAME

This year's ROV is the revision and improvement of what was presented last year due to the great potential that the members of TecXotic saw in said proposal. The main mechanical improvements to highlight in the frame for this edition are a new grip mechanism for critical components, structural reinforcement in areas that presented deformation at the end of last season of the MATE ROV Competition, and improvement in the internal distribution of components to reduce empty spaces.

TecXotic's commitment to the environment and continuous innovation led to the second great contribution of the frame, which is the use of "PolyAl", a sustainable Cellulose-Aluminum-Plastic Composite construction panel known in Latin America as "PoliAluminio", this material has several advantages, the first of which is that it is a 100% recycled material, since to produce one kilogram of this material, 140 multilayer "Tetra-Pak" containers were used. In addition, “PolyAl”is waterproof, impact resistant, flexible, and its density varies between 0.98 and 1.1 g/cm3, making it neutrally buoyant, which doesn’t affect the flotation of the ROV.

C. PROPULSION LAYOUT

The eight-thruster configuration continues to be an essential part of TecXotic's ROV design because it provides great maneuverability with better displacement and precision when performing underwater tasks.

Atzin 2.0, like its predecessor, uses only Blue Robotics® T200 Thrusters. According to the manufacturer’s experimental data, each thruster propeller turns at 1,676 rpm and provides an approximate thrust of 1.5 kgf with a power consumption of 54.4 W at 16.0 V. This provides enough thrust for horizontal or vertical motion without needing the thrusters to be at full throttle, reducing power consumption and extending their usable life.

The propulsion system allows motion in three perpendicular axes (surge, sway, heave) and rotation around one (yaw). Motion around the heave axis is a priority due to the challenge of stability that demands four thrusters at the same height. Four of the eight T200 thrusters were mounted horizontally on each of the frame’s corners at an angle of 45°.

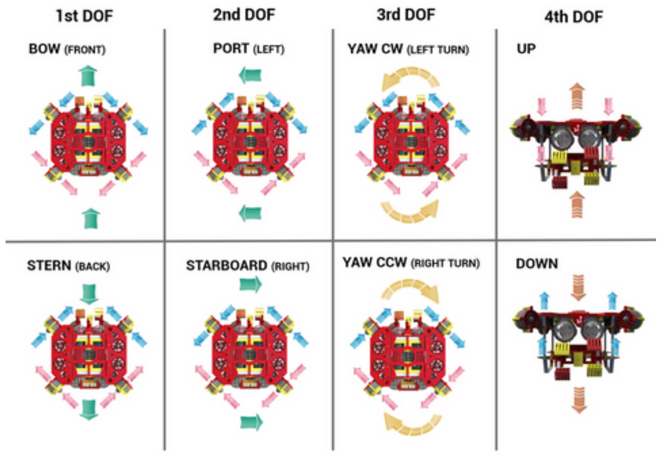


Fig. 23 "Propulsion layout"

D.ELECTRONIC ENCLOSURE

The electronic housing is split into two cylindrical acrylic containers by Blue Robotics (Watertight Enclosure for ROV 4" series). The affordability, reliability, and versatility are reasons why TecXotic decided to use these components versus developing them from scratch. Rated for depths of up to 100m, the cast acrylic tube provides the necessary space for the electronic components. Due to the transparent material, the use of cameras and a visual inspection are not a problem. Hermeticity is possible due to the use of O-ring seals in the end caps of the cylinder in combination with penetrators which seal the electrical cables as they pass into the enclosure.

As part of the safety protocol, a vacuum test is performed every time before starting poolside operations according to the company's JSA. The internal pressure of each enclosure is decreased to -15 Bar (depth of 152.9 Msw) and it has to be maintained for 15 minutes without increasing more than 3 Bar.

Other advantages of the cylindrical containers are the variety of end caps and the stress distribution. In the current configuration of the ROV different end caps are required to fulfill diverse objectives, an optically clear acrylic dome is perfect for camera visibility. The connections with the exterior are handled by aluminum end caps with holes and penetrators. Due to the circular shape, the stress is distributed evenly along the cylinder avoiding shear stress in the corners as is the case of square enclosures.

Being able to see in low light conditions and being able to clearly discern the target such as coral fragments of plastic debris in intricate environments like estuaries, rivers, or bays led to the design of a special camera support with a degree of freedom provided by a servomotor. This support is printed using 3D PLA filament.

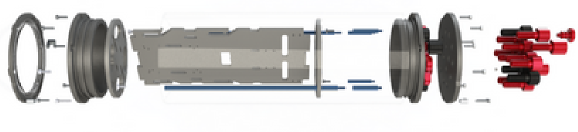


Fig. 24 "Exploded enclosure view"

E. BUOYANCY

The unpredictability of conditions in environments such as rivers, lakes, or other marine environments led Tecxotic to a decision of how the buoyancy of Atzin 2.0 should behave.

The buoyancy is the upwards force applied by any liquid to an object submerged in it because of pressure, the free body diagram is shown below. Having a 0 to little positive buoyancy is good for safety, this prevents Atzin 2.0 from getting stuck at the bottom if the motors fail, however, this buoyancy needs to be low because otherwise the motors will need to use more power to move the ROV. The design is made with this consideration and every time a new version is made, a spreadsheet is used to calculate its buoyancy so weights or floats can be added to adjust floatability.

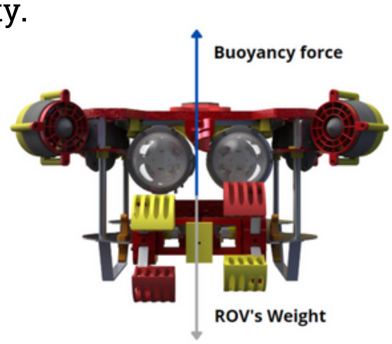


Fig. 25 "Floatation diagram"

Volume (m^3)	0.00912	Obtained from SolidWorks
Liquid density (kg/m^3)	992	External data investigation
Buoyancy (N)	88.7514624	$g\rho V$ (density and volume from liquid)
ROV mass (kg)	14.2	Meassuring
ROV weight (N)	139.302	gM ROV mass
Flotability (N)	-50.5505376	$Buoyancy - W_{ROV}$
Buoyancy needed to achieve neutral bouyancy	50.5505376	

Fig. 26 "Buoyancy calculations"

It is important that the center of mass and the buoyancy center must be aligned in order to ensure the stability of the vehicle, which is important since it makes it easier to use the tools and complete the tasks. To do so, not only should the mass be the same on both sides of Atzin 2.0, they also have to displace the same volume of liquid.

A buoyancy analysis was done using experimental data and the Archimedes principle, taking in consideration measurements like the ROV's weight and volume, the CAD model for this specific task, and the floatability system were analyzed to determine how much force it would exert on Atzin 2.0.

F. Dynamic Floats

Last year's adjustable buoyancy system was one of TecXotic's main contributions to buoyancy in recent editions of the competition, so the idea was reused and the existing designs adjusted to the new ROV geometry.

Two 3D-printed float containers distributed at the sides of the Thrust Deck can accommodate up to 493 cm3 of float straps to increase or decrease floatability in specific locations.

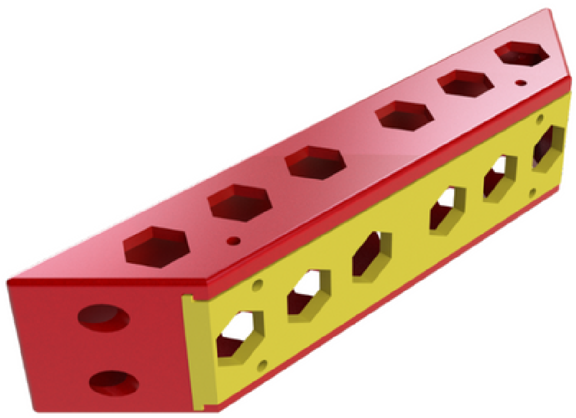


Fig. 27 "Lateral Floats"

G. Tensor Relief

The tensor relief is centered at the top of Atzin 2.0 consisting of a 3D printed ball with a clamp/headband that presses the cable, so, when pulling the cable the ball stays in its place; this ball fits inside a little octagonal-like shape that is connected to the frame of Kolop (a previous design) with graf nuts and screws, and when the tether is pulled, the force is redirected to the ball, then to the octagon and finally to the frame. This arrangement allows the transfer of the tension from the cable to the frame without the risk of damaging the connections while allowing cable movement, which helps Atzin 2.0 to maneuver easily when going through marine environments.

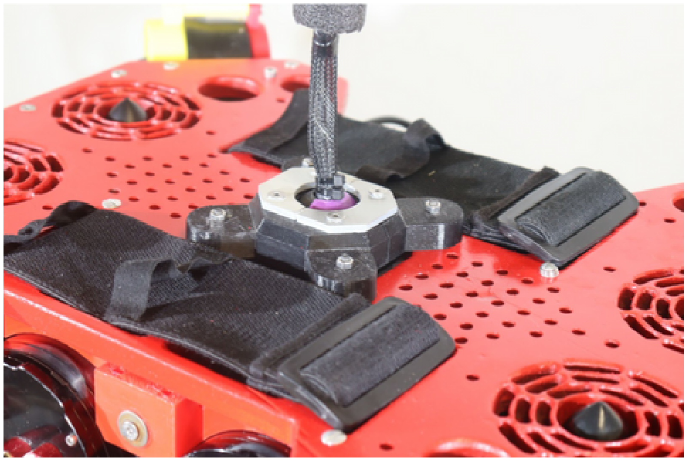


Fig. 28 "Tensor relief"

H. Enclosure Supports

Flexible bands fix the electronic enclosures in place. This gives us two improvements compared to previous solutions, they simplify the task of removing the electronics enclosures since it does not require loosening screws or the use of specialized tools. They apply uniform pressure over a larger area so there is no risk of stress concentration on these critical components.

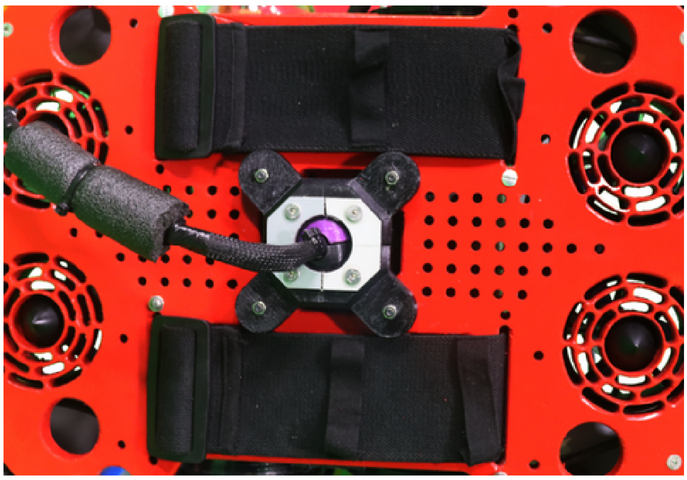


Fig. 29 "Enclosure supports"

I. THRUSTER GUARDS

The thruster guards were designed using Solidworks for the side thrusters responsible for the surge, sway and yaw movements and for the heave movement the upper and lower parts of the thruster guards were integrated to the frame to reduce the use of 3D printed parts,take advantage of the mechanical properties of "PolyAl", reducing the assembly complexity. They were specifically designed to cover the motors preventing unwanted objects such as coral fragments or another form of aquatic life from colliding with the propellers.

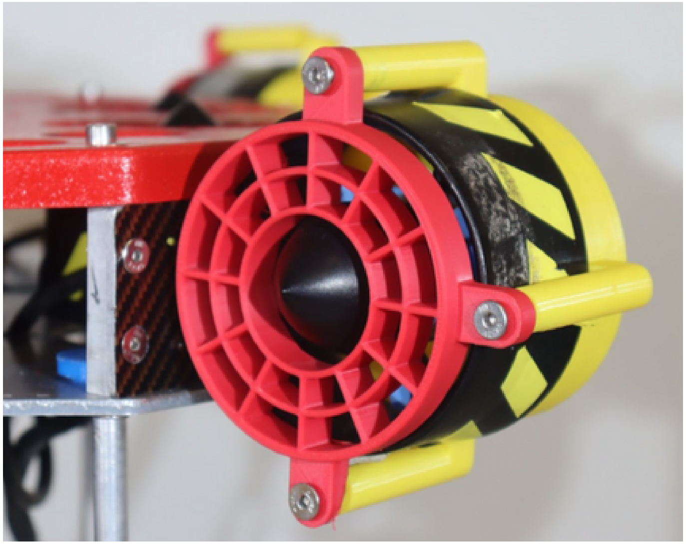


Fig. 30 "Horizontal Thruster Guards"

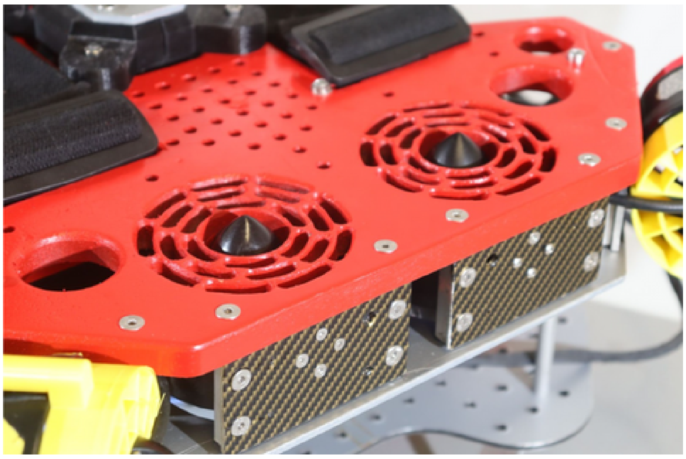


Fig. 31 "Vertical Thruster Guards"

9. TOOLS OVERVIEW

Atzin 2.0 is equipped with certain tools that make it capable of doing the tasks included in the RFP requirements. The implementation of tooling allows Atzin 2.0 to perform the following activities: moving equipment like connectors, cameras or solar panels, collecting debris and biofouling from underwater installations in order to clean it; recognizing seagrass habitats, and also reintroducing endangered species of fish; maintaining the waterways healthy; removing marine algae, as well as being able to create a 3D model of a coral head.

A. DOUBLE CENTRAL CLAWS

A double multi-purpose gripper was strategically placed in the ROV's front tool deck. This configuration helps with tasks such as attaching mooring connectors or removing biofouling. Its parts were 3D-printed using PLA, incorporating a modular design for easy replacement in case of failure or breakage. The tool uses a worm-gear mechanism as its main mechanism to achieve greater precision when opening or closing the gripper.

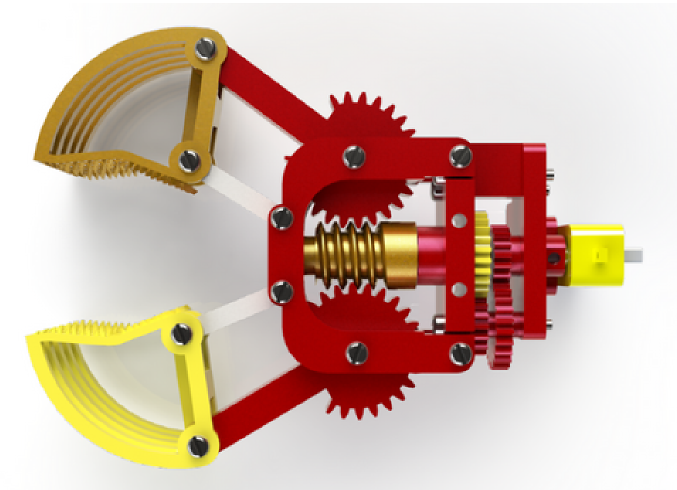


Fig. 32 "Gripper's Side View"

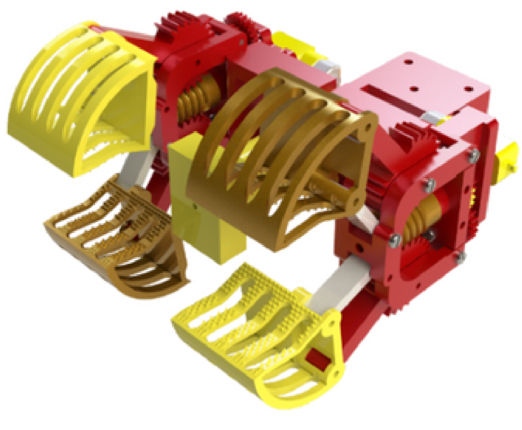


Fig. 33 "Double Grippers"

B. FRY CONTAINER

Located at the back of the tool deck and powered by a 9.0 V DC motor, this system consists of a main body made out of 3D printed PLA parts. Designed to transport Northern Redbelly Dace or other small fish around 1-4 inches. The fry container allows Atzin 2.0 to transport and safely release living creatures without exposing them to the tools, thrusters or frame of the ROV. The tool uses a Worm-gear mechanism as its main mechanism to achieve greater precision when opening or closing the lower part of the container.

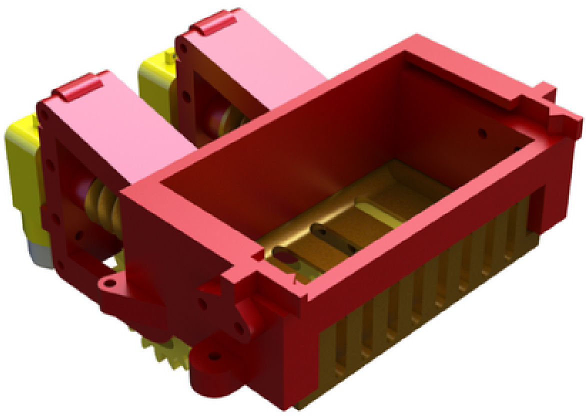


Fig. 34 "Fry container"

C. SAMPLE COLLECTOR/ RX ADMINISTER

This tool has two functions: the first is to provide UV light for diseased corals and the second is to collect a water sample for further study. This is possible thanks to the conical geometry that allows the alignment of the tool with the target. The light source is a 10 W LED while the sample is collected using a submersible pump, both devices run on 12 V supplied by the ROV.

Fig. 35 "Sample collector"

10. NON-ROV DEVICE WASP

Compared to last year, WASP has an improvement in its communication system by limiting its usage. It has a new color communication functionality to indicate its current status. Additionally, it features handles to facilitate handling in the water.

The Non-ROV device is activated by releasing it at the desired point. It descends, and upon making contact with the water or experiencing zero acceleration, it begins to perform its task.

The float operates with a suction motor, a solenoid, and an air pump connected in the same system to manipulate a pressure bag with the objective of changing the device's buoyancy. This system is controlled by a series of sensors that determine the float's position in its environment.

Fig. 36 "WASP"

11 TESTING AND TROUBLESHOOTING

The first stage of testing are the digital simulations to reduce time and waste during prototyping. After the design has accomplished the objectives of the SMW philosophy, the design is manufactured using the corresponding technology. Additive manufacturing is used for the ROV's tools and CNC router for larger parts or parts that fulfill a structural function. Tests are carried out to verify the durability, reliability, and repeatability of the tools.

Appendant 3 - Non ROV Device SID

12. CONCLUSIONS

A. RESULTS

Atzin 2.0 is the combination of a lot of past experiences, effort, time, and passion given by every collaborator in TecXotic, but represents the dreams of dozens of students that have worked between the MakerSpace walls imprinted into an ROV. Every mistake, every lesson, every laughter, every tear, every consultation with mentors, everything has led to this, and TecXotic is ready to take Atzin 2.0 up where it belongs.

B. CHALLENGES

The consequences of the post-pandemic of COVID-19 and the company organization were the main challenges that TecXotic faced during this year, but thanks to the passion, dedication, and perseverance of the new and already experienced collaborators of TecXotic who seek to keep the project alive the workflow, the protocols, and the characteristic enthusiasm of the company could be carried on.

C. FUTURE IMPROVEMENTS

The constant search to improve and innovate in the different areas has always been present in TecXotic's mindset. The company is proud of having a philosophy that has allowed it to expand the knowledge gained in each edition of the competition. But it is also important to pass on the acquired knowledge effectively to future generations. That's why, the company will focus its efforts on creating guidelines for the fundamental aspects for each work area and will create best practices that reduce the waste of both human and material resources.

D. LESSONS LEARNED AND SKILLS GAINED

TecXotic is more than just a team; it is a community of like-minded individuals who share a common goal: to push the boundaries of technological innovation and explore the wonders that lie beneath the surface. The MATE ROV Competition has served as a catalyst for the team members of TecXotic to unleash their creativity and problem-solving abilities. From designing and building their underwater robots to navigating through intricate tasks, the competition presents an array of challenges that require both technical expertise and strategic thinking. The team members are pushed to think outside the box, constantly brainstorming ideas and refining their designs to overcome the obstacles presented by the competition.

But the impact of the MATE ROV Competition goes beyond the technical aspects. It has transformed the lives of the team members, shaping their dreams and aspirations for the future. Through the competition, they have learned valuable lessons in teamwork, leadership, and perseverance. They have developed a deep appreciation for the collaborative nature of scientific and engineering endeavors, understanding that true innovation is often born out of collective effort.

As TecXotic continues its journey in the MATE ROV Competition, they inspire others to dream big and embrace the power of collaboration, innovation, and exploration. Their story serves as a testament to the transformative impact of pursuing one's passions and the profound influence of platforms like the MATE ROV Competition in shaping the dreams of future generations.

13. ACKNOWLEDGEMENTS

Our Alma Mater, Tecnológico de Monterrey, Campus Cuernavaca - For its generous funding, working facilities and passion for education.

Tecnológico de Monterrey

MATE Center and Marine Technology Society - For sponsoring the 2023 International Competition and inspiring us to create "The ocean we need, for the future we want".

MATE ROV COMPETITION

TecXotic Mentors:

- **David García MBA -** For always believing in us, and for inspiring us every day. For always showing us that passion for what we do is the ultimate goal in life.
- **Jesús Simental Ph.D. -** For your unconditional support and fun nights. But most importantly for showing us the importance of loving what you do.
- **Javier Montiel M.Ed. -** For being our mentor, unconditional guidance and support as a STEM ambassador. For showing us the importance of loving science.
- **Miguel Pérez BSc -** For joining us on this adventure since 2021 and now as a mentor for your patience and knowledge in the software areas.

Tecnológico de Monterrey Campus Cuernavaca

- **Abel Angelina, Mr. -** Media Lab Coordinator
- **Zazil Loewe, B.A. -** Communication Leader
- **Ignacio Merlín, B.A. -** Maker Space Coordinator (TecXotic HQ)
- **Alfredo Nava, B.A. -** Advanced Manufacturing Lab Coordinator
- **Salvador Fuentes, Mr. -** Applied Engineering Center Coordinator
- **Antonio Flores, Mr. -** Campus Security Coordinator
- **Ricardo Valera, MSc -** Electronics Professor
- **Sergio Hernández, MSc -** Computer Science Professor
- **Alejandro Salgado, MBA & Staff -** Director of Student Services and Experiences
- **Jorge Álvarez, Ph.D. -** Director of the School of Engineering and Science
- **José Moya, MBA -** General Director

Tecnológico de Monterrey, South & Central Region

- **Jorge Reyes, Ph.D.** - Director of the Mechatronics Department, South & Center Region, Tecnológico de Monterrey.
- **Julio Noriega, Ph.D.** - Dean of the School of Engineering and Science, South & Center Region, Tecnológico de Monterrey.
-

Tecnológico de Monterrey

- **Feniosky Peña-Mora Ph.D.** - Dean of the School of Engineering and Science, Tecnológico de Monterrey.
- **Juan Pablo Murra, Ph.D** - Rector of professional and graduate, Tecnológico de Monterrey.

Our Sponsors

For believing that education and passion is the future of our country. And specially, for bringing this group of passionate thinkers to their dreams.

WÜRTH

Planeta LISTO ayúdanos a ayudar

makermike.io.16.com

14. REFERENCES

Bucks Local News. (2012, March 19). Environmental group: Delaware River tops list of most polluted waterways. https://www.buckslocalnews.com/news/environmental-group-delaware-river-tops-list-of-most-polluted-waterways/article_b94c90d5-a5c1-5c8e-b39d-2319fa2a511a.html

Charlton, E. (2019, June 19). Microplastics have spread right to the sea bed, study finds. World Economic Forum. https://www.weforum.org/agenda/2019/06/underwater-robots-have-found-microplastics-from-the-surface-to-the-seafloor/

Hawaii Public Radio (2019, October 24). 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

Oceaneering. (2013, November 01). Americas Region HSE Employee Handbook 2012. https://files.materovcompetition.org/HSE_Handbook_number_3_As_of_11_19_2013_AW.pdf

Reef Resilient Network. (n. d.). Field-Based Nurseries.

https://reefresilience.org/restoration/coral-populations/coral-gardening/field-based-nurseries/

The Global Compact. (2013). Who cares wins. https://d306pr3pise04h.cloudfront.net/docs/issues_doc%2FFinancial_markets%2Fwho_cares_who_wins.pdf

UN Department of Economic and Social Affairs (n. d.). The 17 Goals. https://sdgs.un.org/goals

APPENDANT 1

CRITERIA	ATZIN	ATZIN 2.0	GOAL	RESULT	GA
Overall Width	0.54 m	0.58 m	▼	▲ 7.4 %	NA
Overall Length	0.69 m	0.59 m	▼	▼ 14.5 %	A
Overall Height	0.36 m	0.35 m	▼	▼ 2.8 %	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	13.6 Kg	14.2 Kg	▼	▲ 4.44 %	NA
Tether Mass	3.2 kg	3.2 kg	-	-	NC
# Modular Floats	56	6	▼	▼ 90%	A
# ROV Parts	276	173	▼	▼ 37.2 %	A
# ROV Tools	5	3	▼	▼ 40%	NC
# Diff. nuts & bolts	4	6	-	▲ 25 %	NA
# Diff. Actuators	3	1	▼	▼ 66.66%	A
Horizontal Thrust	58.8 N	58.8 N	-	-	NC
Vertical Thrust	58.8 N	58.8 N	-	-	NC
Horizontal Speed	0.67 m/s	0.76 m/s	▲	▲ 13%	A
Vertical Speed	0.55 m/s	0.62 m/s	▲	▲ 12%	A
Degrees of Freedom	4	4	-	-	NC
Power Consumption	223.6 W	223.6 W	-	-	NC

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

APPENDANT 2

GOODS & SERVICES

Part Name	Description	Expense	Repurposed	Sponsored
Thruster 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	--	--
Cameras System Expenses				
Part Name	Description	Expense	Repurposed	Sponsored
Cameras system components	Aqua-Vu AV 715C // CCTV Recording System	--	$ 457.99	--
	Angular camera (4) // Silicone mold	$ 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 // 1/4 x 3/4 bolts// Advanced Sanding Sheets (6-Pack) // 40x M5 Hex nuts 50 pieces box // 40x 12x M5*55 mm Hex screw // 10x M6*60mm Hex screw	$ 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	--
Actuadors	10 watts led, sumersible pump, 4x 5v 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	--	--

INVESTMENT

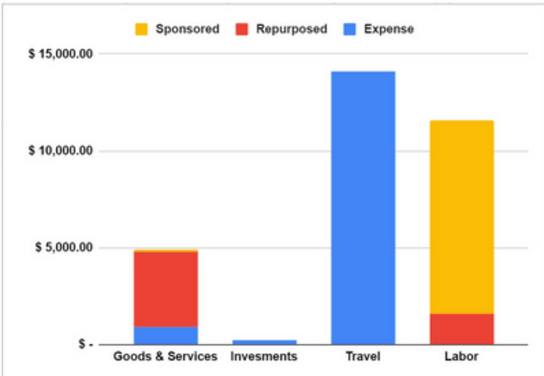
Machinery & Tooling		
Type	Part Name	Expense
Machinery	Lathe cooling system	$ 60.00
Tools	Cutters & drills	$ 30.00
Tools	Crimpers	$ 25.00
Tools	Wrenchs	$ 130.25

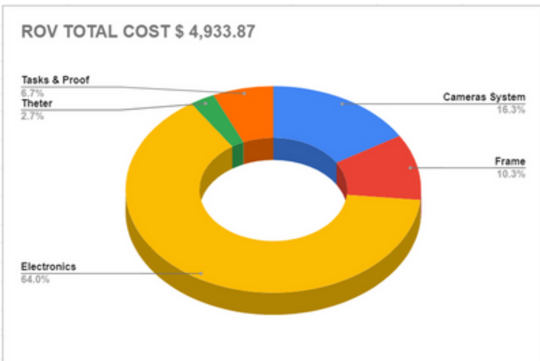
TRAVEL

Travel Cost (12 people)		
Type	Part Name	Expense
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

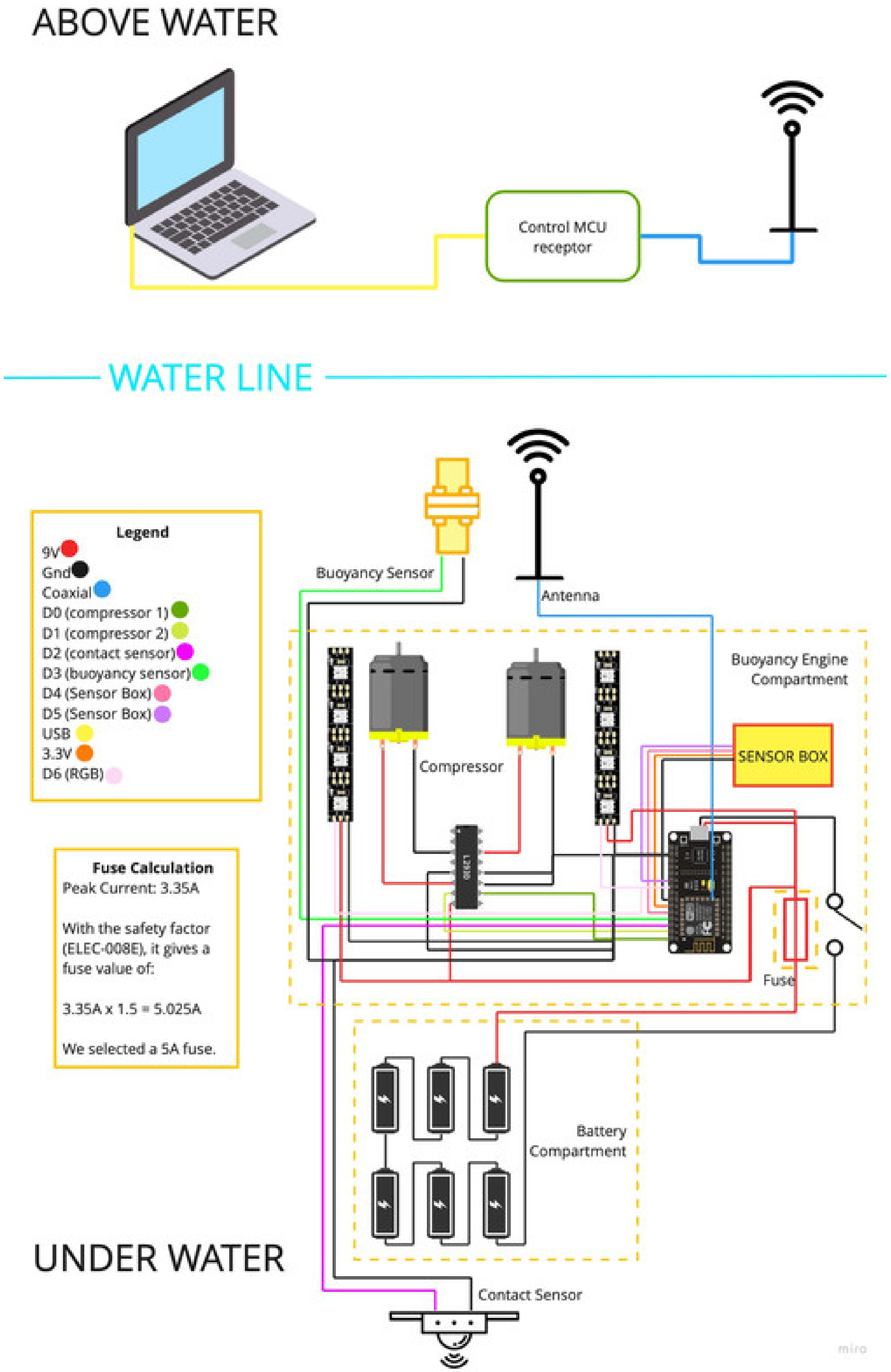
Labor Cost		
Type	Part Name	Expense
Uniforms for 25 people		$ 1,250.00
Personal protection equipment		$ 350.00
Design & manufacturing labor		$ 10,000.00





	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

APPENDANT 3


ABOVE WATER
Control MCU receptor
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.
Buoyancy Sensor
Antenna
Buoyancy Engine Compartment
Compressor
SENSOR BOX
Fuse
Battery Compartment
UNDER WATER
Contact Sensor
miro