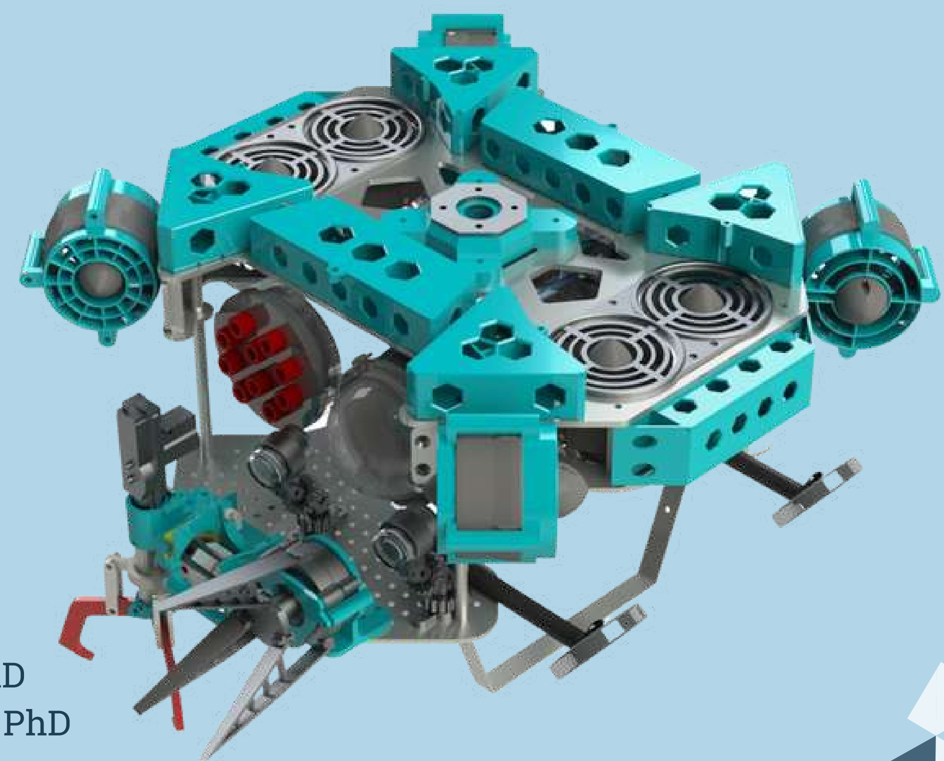
TECXOTIC

TECHNICAL REPORT 2022

Cuernavaca
Morelos
México



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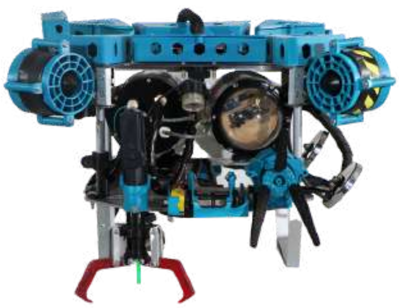


Fig. 3 "CCU"

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:

- CCU: Case-Control Unit

1. ABSTRACT

Since its foundation in 2015, TecXotic has embraced a design philosophy that emphasizes simplicity, extensive modularity, quality, and safety. This year, our company has poured a rigorous effort into our novel and most innovative ROV: Atzin, which means “drop of water” in Nahuatl, one of the most important indigenous languages in Mexico.

With seven years of experience and a highly qualified company of 44 collaborators, TecXotic is a company with expansive expertise in the design and production of technological solutions for ecological marine issues, giving equal importance to results and the safety measures kept, because “who cares always wins”.

Atzin was designed with extensive capabilities to fulfill a myriad of tasks in various underwater environments, while adhering to Marine Renewable Energies, protecting the environment, and contributing a drop of fresh water into a sea of problems like climate change by facilitating adequate offshore aquaculture, preserving natural blue carbon deposits, and complying with different UN’s Sustainable Development Goals such as Zero Hunger, Climate Action, and Life Below Water, among others.

This year, decks are introduced as a new way of tool distribution, which elevates modularity, addressing needs such as maintenance of marine energy generators, management of fish populations in aquaculture installations, maintaining seagrass in optimal levels, and assisting wreckage salvage operations.

This report aims to inform the reader about the ideation and development of Atzin, including mechanical design, software development, electronics, corporate responsibility, and the safety measures taken for the successful accomplishment of its designated tasks.

Fig. 4 "TecXotic 2022"

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 to the collaborators total confidence and comfort, allowing correct manufacturing processes, task completions and hazards avoidance.

Fulfilling international standards and protocols for safety regulations is essential for TecXotic, just as it is to teach and show the company's safety protocols in the lab and in the work field. Nonetheless, just complying with standards is not the reason for safety's importance. "Who cares, always wins" is the company's philosophy, and TecXotic cares, promoting and ensuring a safe, organized and clean work environment for collaborators.

B. LABORATORY AND WORKSHOP SAFETY PROTOCOLS

For this year, an improved version of last year's safety handbook was made, quick access is granted to all collaborators at any moment, while being constantly updated and revised. Safety Awareness is a key aspect; therefore, the content of safety information, protocols and manufacturing procedures the company has, including Standard Operation Procedure (SOP), Job Safety Analysis (JSA), and safety data sheets.

C. ROV SAFETY PROTOCOLS

TecXotic designed JSAs to guarantee the proper handling of Atzin, facilities, equipment, and resources. A safety checklist was developed for pre-immersion and post-immersion (included in the JSA), minimizing accidents or mishandling during Atzin's operation and transportation. This is extremely important because it ensures the safety, well-being, and physical integrity of collaborators and operators.

Fig. 5 "Safety lab protocols"

D. SAFETY FEATURES

Atzin features status light indicators and safety stickers to indicate areas that should be kept clear. 3D printed PLA guards for the thrusters that avoid collisions with the propellers. Enclosure penetrators are sealed according to the Safety Handobook's SDS, while the frame was designed with stability in mind.

Fuse calculations for the ROV and non-ROV device 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. Another important aspect is the improvement made to Atzin's floatability with respect to Kolop, which facilitates recovery in case of shut-down.

Fig. 6 "Safety lab protocols"

Fig. 7 "Atzin"

3.DESIGN RATIONALE

A.DESIGN METHODOLOGY

TecXotic's design methodology stands with three pillars: the lessons acquired throughout the years, the specific tasks and challenges of each edition, and doing more with fewer resources in favor of sustainability through the SMW philosophy. This ensures TecXotic's achievable and plausible results.

Kolop was TecXotic's ROV in 2021; conceived from a mindful analysis of the lessons learned from the previous five years of ROV development, it generated a meticulous redesign with outstanding results.

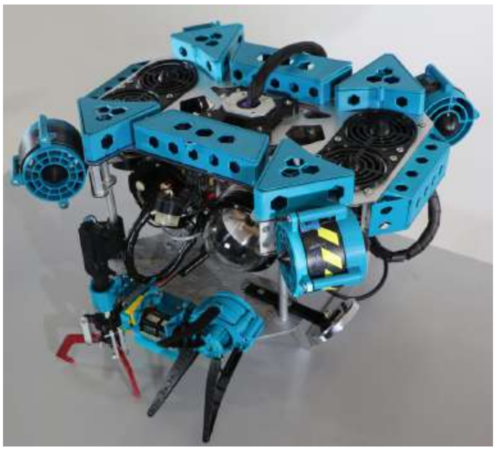


Fig. 8 "Atzin"

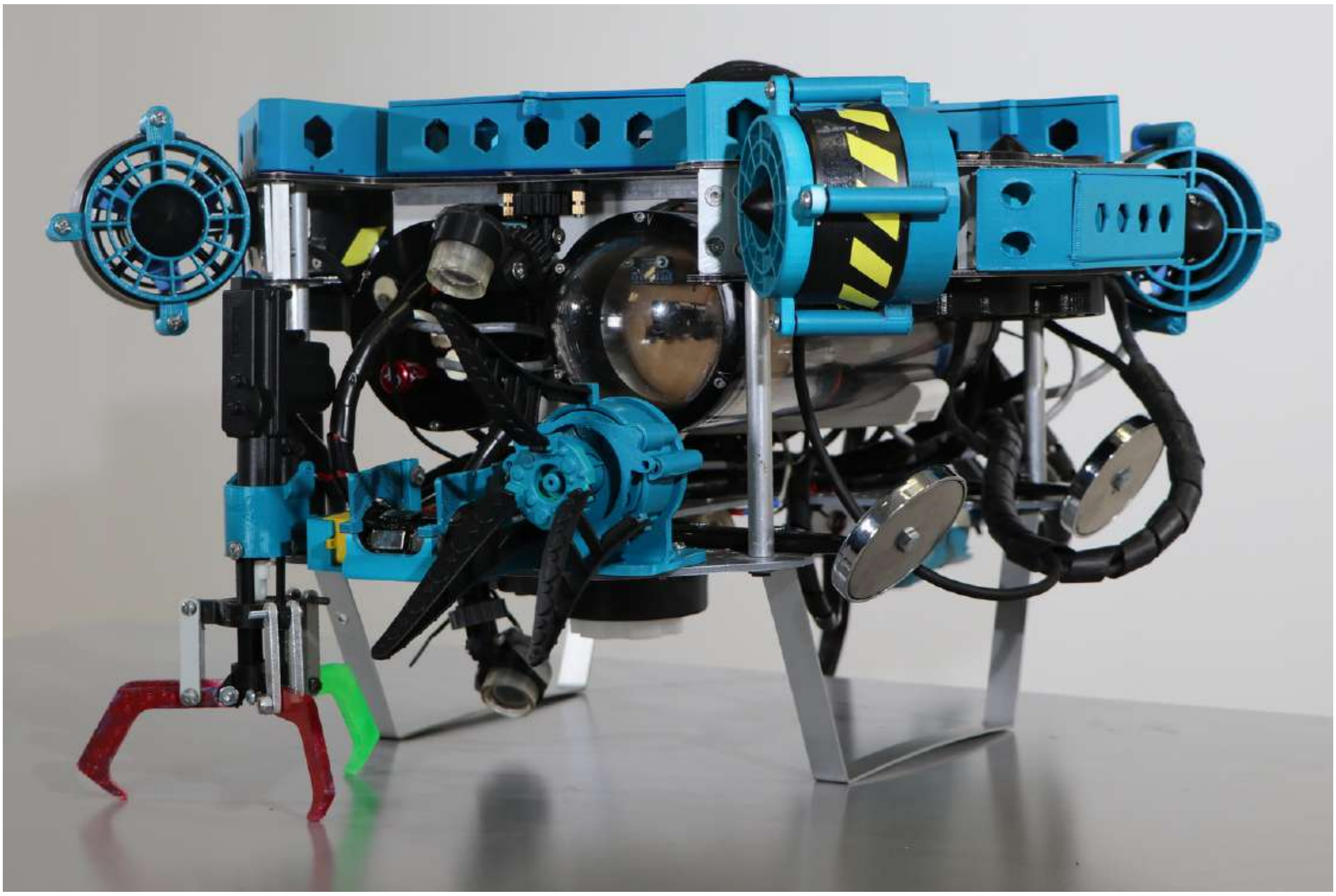


Fig. 9 "Atzin"

Because of this, for 2022, the design starting point is Kolop. All TecXotic collaborators hosted several evaluation and feedback meetings and after running diverse Failure Mode and Effect Analysis (FMA) for Kolop, 10 design guidelines and recommendations were defined for Atzin:

1. MANTAIN safety practices & protocols.
2. INCREASE ▲ portability.
3. DESIGN adjustable bouyancy.
4. DESIGN modular and versatile tools.
5. DECREASE ▼ assembly complexity.
6. IMPROVE computing & processing capabilities.
7. IMPROVE user interface.
8. IMPROVE standarization of components and parts.
9. DECREASE ▼ power consumption.
10. INCREASE ▲ maneuverability

Fig. 10 "Design Guidelines"

These guidelines not only contribute to the development of an improved ROV, but also to the reduction of the environmental impact caused by TecXotic's processes and products. Atzin's development began by convening senior and junior collaborators of TecXotic for an immersive week of ideation, design, and prototyping. Using the Design Thinking Methodology, at the end of these sessions the company generated 4 mockups, aligned to our guidelines and task specifications, which laid the foundations for Atzin's final design.

Fig. 11 "Immersive Week ROV Prototypes"

Atzin is not just the result of the hard work during this year, it carries within it the legacy of its predecessors.

B.DESIGN PHILOSOPHY

The SMW methodology exemplifies constant generational improvement since its first iteration in 2019. In a nutshell, the methodology describes the following principles:

SMW Simple Modular Well-done

Fig. 12 "SMW Methodology"

- **S:** The simplification of designs down to essential elements without compromising their functionality; 13.4% mass reduction, 16.0% part reduction and 22.6% power consumption reduction are examples of this.
- **M:** Application of interchangeable tools and division of Atzin's decks into the tool and thrust deck for easy substitution, updates, and check-ups without the need for complete or complex chassis disassembly.
- **W:** Use of 5s and RUP methodologies for standardization of manufacturing, development and testing processes.

4.MECHANICS

A.MECHANICAL OVERVIEW

Atzin's mechanical components play a fundamental role in complying with the design guidelines. The development of the mechanics was oriented towards improving portability and maneuverability through an agile and light design. The modularity increased due to a frame distributed in functional decks as well as adaptive flotation systems. Likewise, the company took special consideration towards standardization of components and accessories in addition to having an assembly-oriented design.

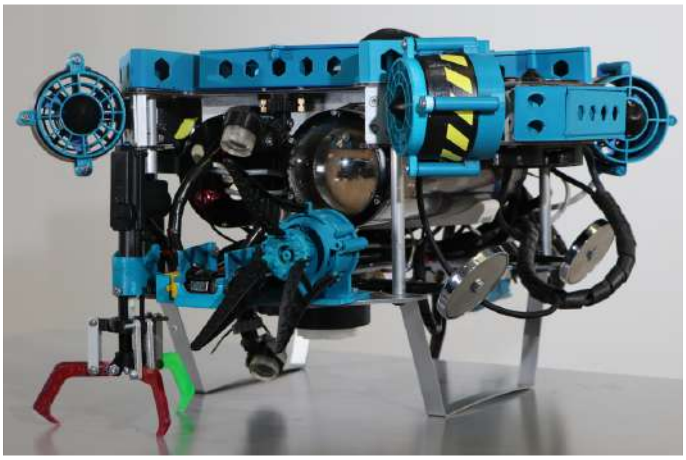


Fig. 13 "Isometric View Atzin's"

B.DESIGN EVOLUTION

Design is an iterative process, thus TecXotic soars through each of the stages of Design Thinking (empathize, define, ideate, prototype, and test), knowing that "The sooner we fail, the sooner we can solve and innovate". It is a process that begins with napkin ideas, cardboard mock-ups, virtual models, modular tests, functional prototypes (MVP), and concludes with the final product.

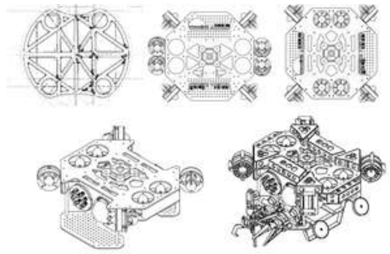


Fig. 14 & 15 "Design Evolution" & "Frame Atzin"

C.FRAME & ENCLOSURE DESIGN

The frame consists of two main Reynobond® decks, divided by multiple aluminum profiles. Following a modular design methodology, Atzin can be divided into subassemblies such as the thruster bracket and tool deck, which can be removed from the frame without full disassembly. The entire frame was designed to be geometrically symmetrical which contributes significantly to the modularity and stability of the entire vehicle.

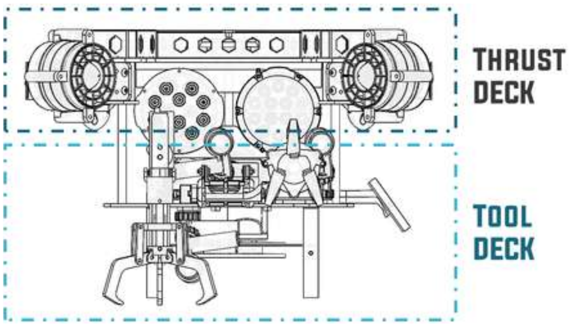


Fig. 16 "Classification of decks"

This new distribution has two main Blue Robotics® cast acrylic enclosures: the Thruster Control Enclosure (TCE) and the Main Control Enclosure (MCE). The enclosure selection was an inherited decision due to their reliability, wherein each one is rated for depths up to 100.0 m.

Also, due to their translucency, cameras can be housed inside and its aluminum flanges allow heat dissipation as well as connections with the outside using airtight penetrators.

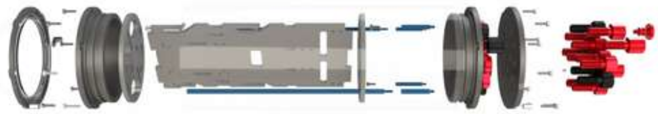
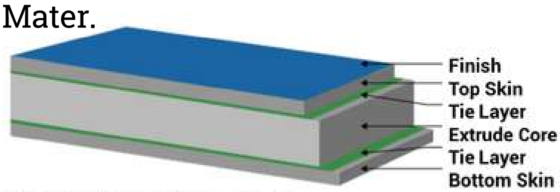


Fig. 17 "Exploded Enclosure View"

Both enclosures are fixed by two holders that arrange them horizontally, an inherited decision due its reliability. This ensures that Atzin's center of mass is located near the midpoint of the enclosure array, increasing buoyancy stability, higher cylinder accessibility, as well as effortless underwater activity according to computer-generated simulations. This configuration allows greater maneuverability while performing quick-access maintenance and service.

Most of the frame is made out of Reynobond® RB160FR, which consists of an extruded 3.0 mm thick, polyethylene core loaded with mineral flame retardant laminated between two aluminum skins. This composite material has excellent properties such as hardness, malleability, and hardness while still being light and resistance to oxidation and corrosion. These pieces are milled with a computer numerical control (CNC) router. In accordance with the guidelines, a huge effort was made to standardize the entire vehicle's nuts and bolts to M5 Allen flat-headed. As one of Atzin's greatest contributions to reducing environmental impact, all of the Reynobond® used comes from recycled material obtained from the renewal of the collaborator's Alma Mater.



Finish: Polyester coating
Skins: 0.5 mm thick 3000 series aluminium alloy panel
Tie Layers: Thermally activated tie-layer
Extruded Core: 3mm thick polyethylene
Density: 170 kg/m3
Minimum Bonding Strenght (ASTM D1781): 100 N-m/m
Allowable Bending Stress: 79.3 MPa

Fig. 18 "Reynobond® Physical Properties"

Atzin has several 3D-printed parts. Most of which are made out of PLA and Eco-ABS. This rapid prototyping technology is used for tools such as grippers, pin pullers, camera supports, thruster guards, and cylinder supports, among others.

D.PROPULSION

The eight thruster configuration provides greater maneuverability, allowing better displacement and precision in comparison to previous positions; water flow is not compromised by the pieces nor by the frame. Atzin is the first TecXotic ROV to use 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 fed at 16.0 V. This provides a maximum combined thrust of 58.8 N for horizontal or vertical motion without needing the thrusters to be at full throttle and reduces power consumption.

E.COMPUTATIONAL FLUID DYNAMICS ANALYSIS:

Ansys Fluent® and SolidWorks® were used to validate Atzin's propulsion design performance before the manufacturing stage. This was done in realistic turbulent water conditions to determine the effect of the thruster motion in water flow and the pressure in the propeller domain.

Atzin's complete hydrodynamic analysis indicates that the flow is uniformly distributed and does not create turbulence or significant drag.

Therefore, the distribution and flow direction of eight thrusters is optimal for motions that require four degrees of freedom (DOF). This gives Atzin enough maneuverability to accomplish all tasks within a three-dimensional envelope.

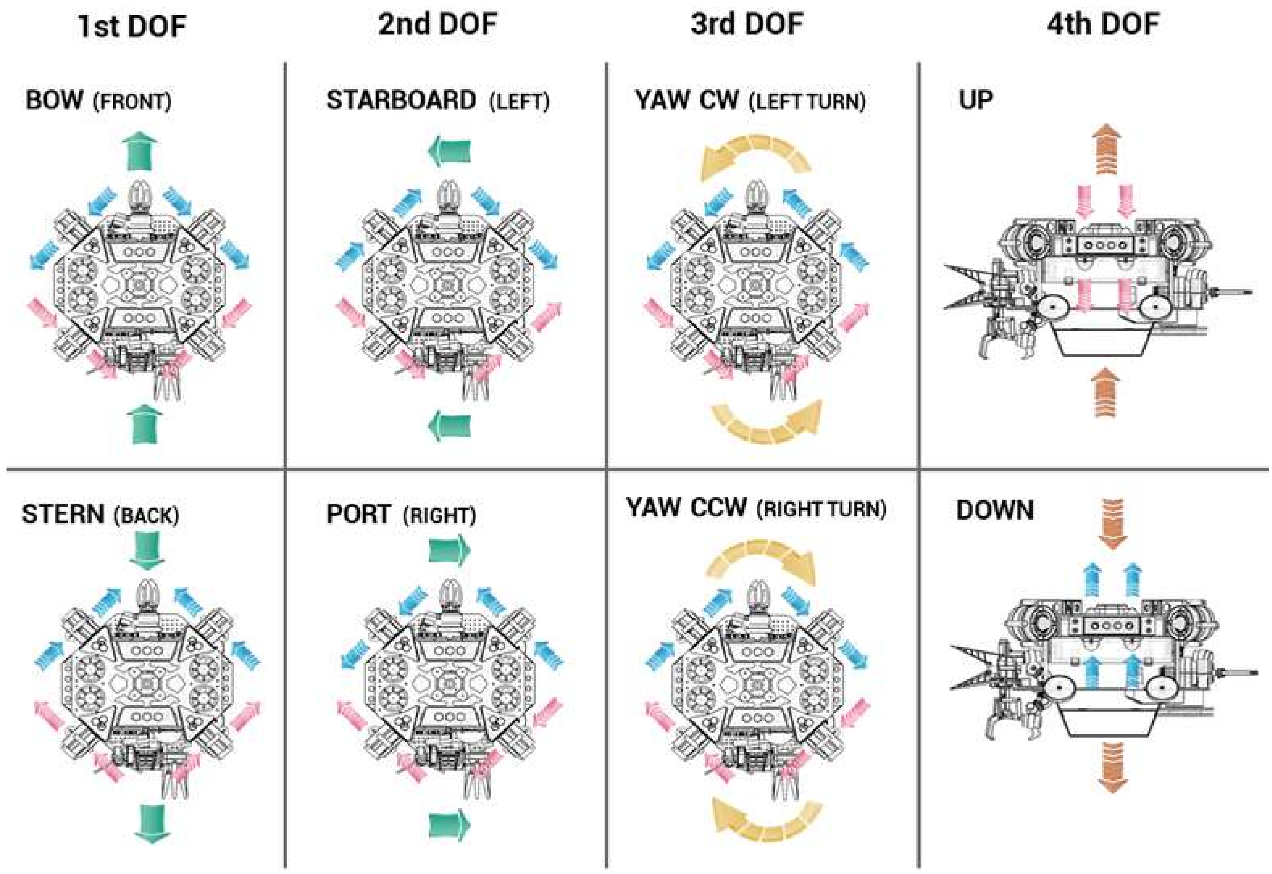


Fig. 19 "Propulsion Layout Atzin's"

F.BUOYANCY

A buoyancy analysis was done using experimental data and the Archimedes principle, taking in consideration measurements like Atzin'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.

By taking in consideration a sum of forces, it can be concluded that the floatability system at its full capacity gives in total a 6.529 N of upward force, which can be easily modified in order to reach a neutral buoyancy. The latter is required to have optimal operation underwater, without the necessity of additional forces in order for Atzin to stay in a specific position. It is also important to mention that Atzin´s center of mass is aligned with the center of buoyancy, so that it is naturally stable and it allows a more precise control for performing the tasks.

Finally, knowing every force existing in the system an acceleration analysis was made using Newton's First Law, where Atzin can have maximum accelerations of 3.6 m/s2 going upwards, 2.7 m/s2 downwards and 3.9 m/s2 sideways.

G.DYNAMIC FLOATS

A new float system is implemented, it allows fine control over floatability with removable float slices that modify forces acting in amount and location. Eight 3D-printed float containers, distributed all around the Thrust Deck can accommodate up to 56 individual float straps to increase or decrease floatability in specific locations.

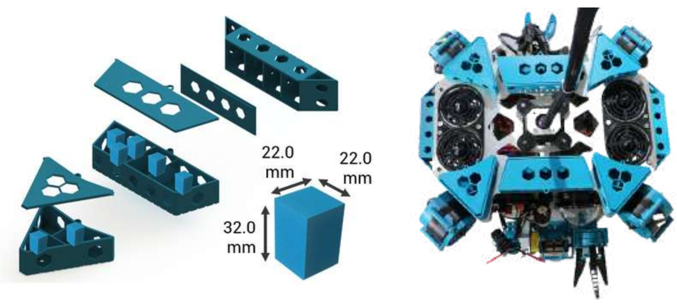


Fig. 20 "Floats Design & Placement"

	TOP CORNER	TOP FRONT	SIDES
VOLUME(M3)	191.6	315.4	177.2
MASS(KG)	0.2	0.3	0.2
FORCE(N)	1.9	3.1	1.7
PIECES	4.0	2.0	2.0
TOTAL FORCE(N)	7.5	6.2	3.5
TOTAL SYSTEM FORCE(N)		17.1	

Fig. 21 "Table of Values on Buoyancy"

H.TENSOR RELIEF

It consists of a 3D-printed sphere that fits inside a Reynobond® cross-shape mounting, compressing the tether with an elastic band so that it can transfer any upwards motion to the mounting. When pulled, the sphere is pushed into its support, absorbing the tension and transferring it into Atzin's frame. The sphere allows movement of the tether in all directions, preventing it from getting tangled.

Fig. 22 "Tensor Relief"

I.THRUSTER GUARDS AND BRACKETS

In accordance with the safety standards established in the RFP, the mesh size is under 12.5 mm to prevent operators from introducing their fingers into the propellers. Previously, thruster guards were difficult to install due the complex design and hard-to-reach thruster configuration.

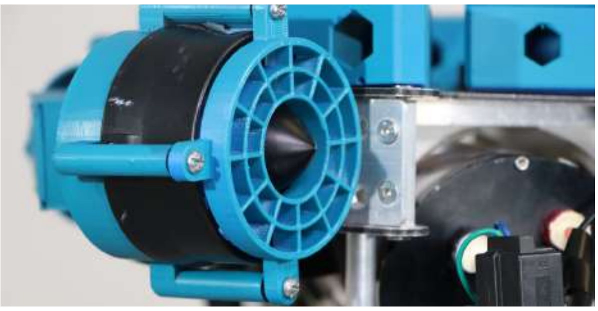


Fig. 23 "Thruster Guard and Bracket"

An innovation for this year's edition is the integration of thruster brackets. Milled out of aluminum, they represent a support for the thrusters that allow easy mounting and dismounting for replacement or maintenance.

J.ROV SHOCK ABSORBER

A shock absorber was made out of aluminum sills in order to take advantage of the material's light weight and considerable durability to resist the stress exerted from bumps expected during normal operation. It is located in the vehicle's bottom section and it is held in place by four screws.

5.ELECTRONICS

A.ELECTRICAL OVERVIEW

Atzin's electrical system design is focused on improving the distribution used in Kolop (2021) while keeping the SMW philosophy by implementing customized PCB boards. Another improvement is the replacement of T100 BlueRobotics® thrusters with T200 BlueRobotics® thrusters, which have higher speed and better maneuverability with the same voltage and current values as the T100 thrusters. Moreover, the average power consumption when Atzin is at top performance is 14.4 A, which constitutes a 22.6% reduction.

The distribution of electrical components considered easy access to the connections and components if modifications were needed. Atzin's electrical system is divided in three main sections: Above the Waterline Electronics (GCU) where operators interact with Atzin, Below the Waterline (TCE and MCE), and the Umbilical cord (Tether) that provides communication and power.

B.ABOVE WATERLINE - GROUND CONTROL UNIT (GCU)

The GCU is where the pilots control Atzin's movement and where Atzin receives all the data from the sensors as well as the video of the analog and digital cameras and displays it. The unit was designed following the strictest safety standards to ensure the wellbeing of the operator. An emergency stop button was implemented to interrupt the 48.0 V power supply if needed. There is also a Littelfuse 25.0 A fuse within 30.0 cm from the 48.0 V power supply as indicated in the RFP.

C.WATERLINE TRANSITION

The tether is a 20.0 m long wired connection between Atzin and the GCU. Minimal cable quantity was a priority in order to improve maneuverability and reduce drag, thus, there are only four connection lines in the tether: two ethernet cables (CAT5e), and the power lines (voltage and ground) coming from the main power source. All connections follow the labeling conditions stated in the RFP.

D.BELOW WATERLINE ELECTRONICS

Atzin contains two electronic enclosures: one is responsible for power management and thruster control (TCE); the second is the main control enclosure (MCE), which is responsible for image recognition, tools control, and is an autonomous system.

E.THRUSTER CONTROL ENCLOSURE (TCE)

The Thruster Control Enclosure (TCE) is equipped with five voltage regulators, each of 200 W, all connected in parallel to the main source. Four regulators are dedicated to the thrusters and Blue Robotics® ESCs. These regulators are set to 16.0 V and the thrusters are distributed in order to have a balanced power output of each regulator. The fifth regulator is set at 12.0 V and provides power to the Main Control Enclosure (MCE) and three H-Bridges that supply five DC-Motors.

Anderson Powerpole connectors were used due to their reliability. The ESCs are controlled by a Pixhawk 4 connected to the MCE.

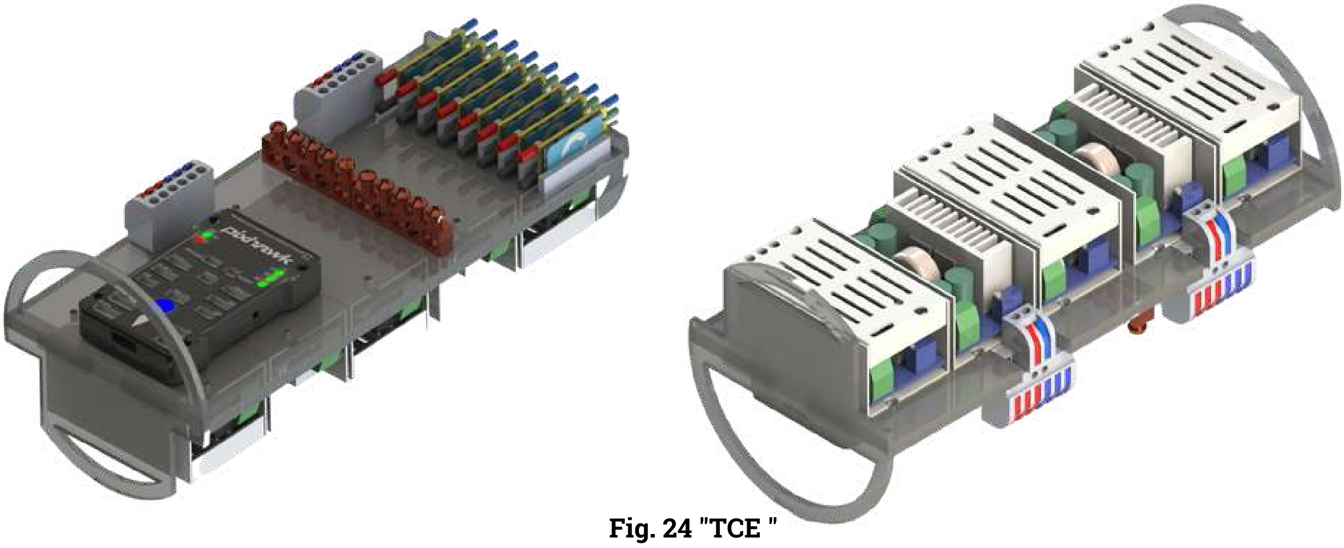


Fig. 24 "TCE "

F.MAIN CONTROL ENCLOSURE (MCE)

Power coming from the TCE reaches a couple of 12.0 V to 5.0 V Step-Down Modules that supply the logic board, the NVIDIA Jetson Nano, and an Arduino Nano. The NVIDIA Jetson Nano board manages communication with the GCU, the digital cameras, the Pixhawk, and the Arduino Nano.

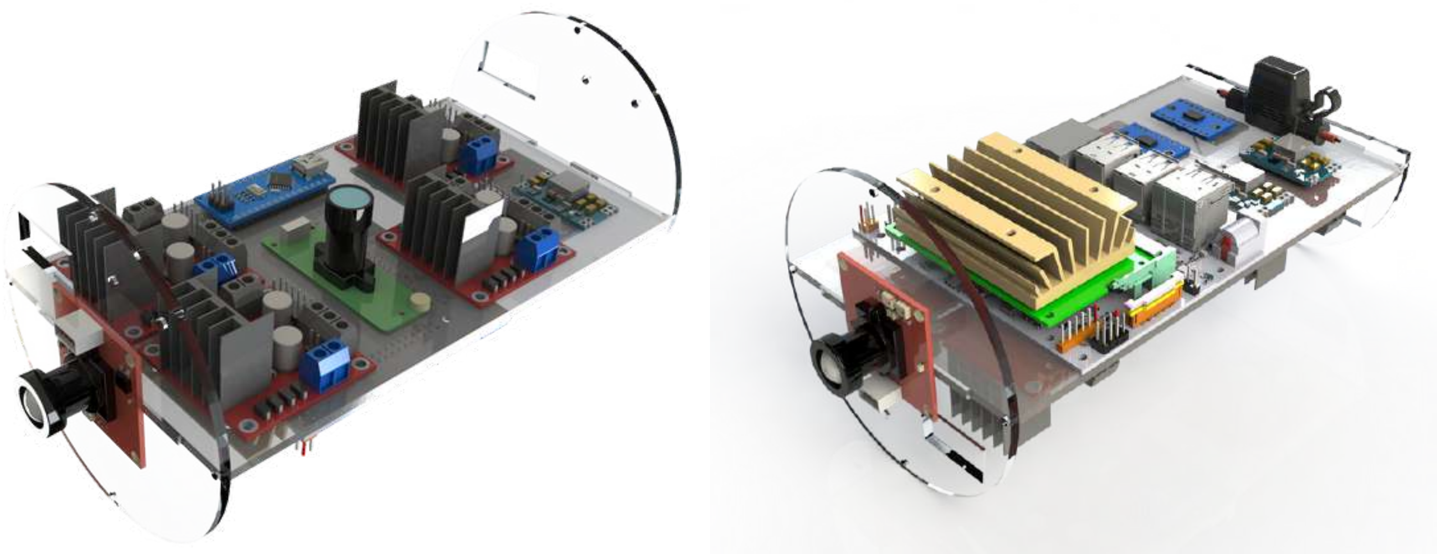


Fig. 25 "MCE"

A major upgrade to the analog camera system is the implementation of a PCB that has a smaller footprint, reliable connections and power supply, and easier connection to the cameras an tether,as it contains its own 12.0 V to 3.3 V Step-Down Module, as well as an Ethernet connector.

Power Budget					
Subcomponent	**Qty**	**Volts (V)**	**Current (A)**	**Total Current**	**Total Power**
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	5	12.00	0.06	0.30	3.60
DC-DC Converter 12 to 5V Efficiency 94% 15A MAX					
Jetson Nano	1	5.00	0.11	0.11	0.55
Pixhawk	1	5.00	0.15	0.15	0.75
GY-6550 Accelerometer	1	5.00	0.00	0.00	0.00
Web Camera Logitech C920	1	5.00	0.03	0.03	0.15
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
4N25 Optocoupler	2	5.00	0.06	0.12	0.6
DC-DC Converter 12 to 3.3V Efficiency 94%					
Analog Camera	5	3.30	0.01	0.05	0.17
Whole ROV system*				**14.42**	223.73
With security factor of 1.50				21.63	

This only includes DC devices

According to the current components requirements, a 58.0 VDC 25 littelfuse 0895025.Z will be sufficient to properly protect the ROV integrity.

Fig. 26 "Power Budget"

G. SID

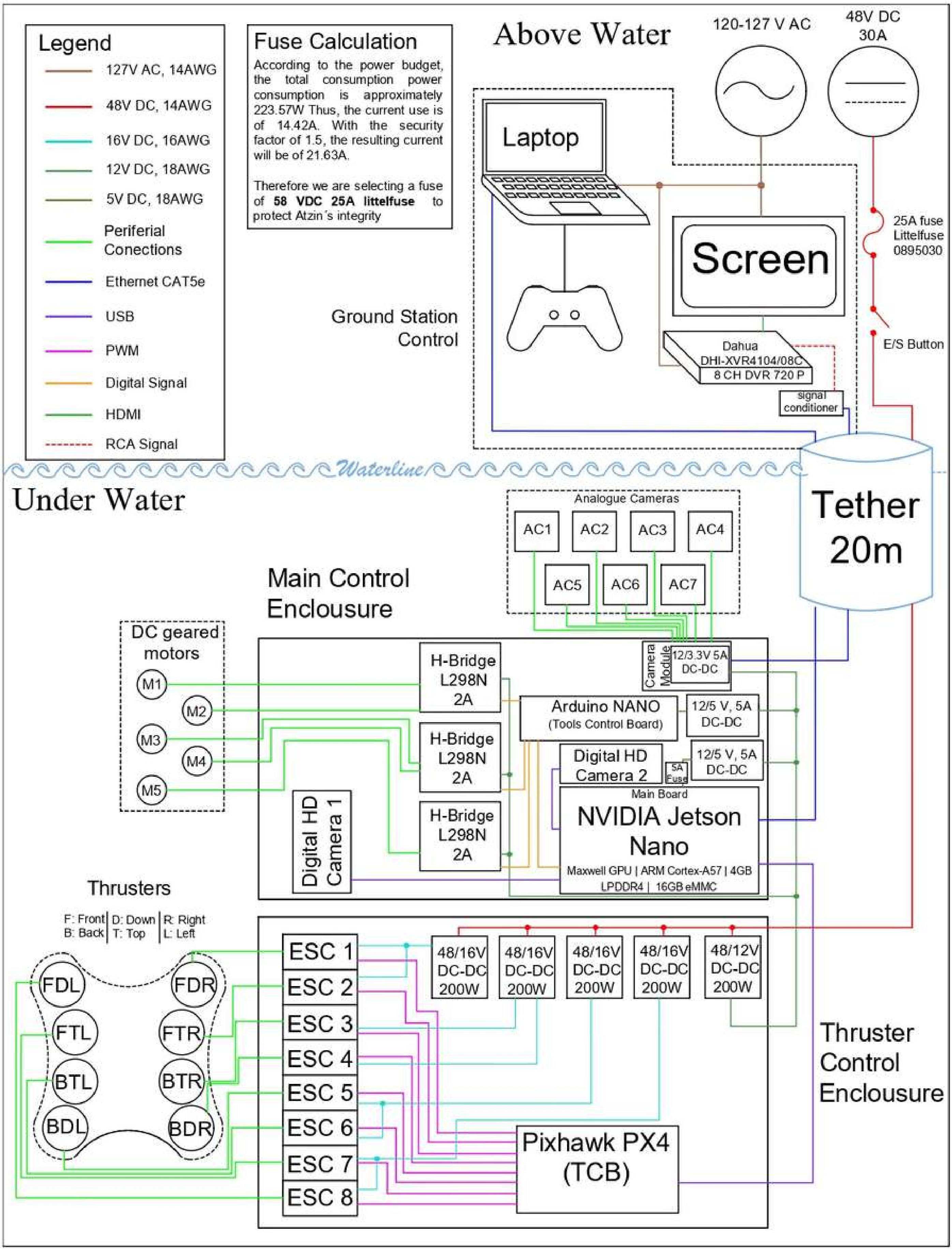


Fig. 27 "Atzin's Electrical SID"

6.SOFTWARE

A.PHILOSOPHY AND OVERVIEW

Tecxotic has a history of high-end software solutions. Based on the cumulative learnings of previous years, TecXotic is proud to present "Ixtli", its brand new interface and control system, the greatest advancement in software the company has developed.

Ixtli is more powerful than ever, highly efficient, capable of processing more data, and has endless growth potential; created in order to satisfy four core needs:

1. **Portability:** system capability to run on any computer device.
2. **Modularity:** reusable system functionalities.
3. **Scalability:** effortless incorporation into future system functionalities
4. **Cost:** lower development cost and easy maintenance.

B.DESIGN AND SOFTWARE ARCHITECTURE

Ixtli is divided into four main sections:

1. Core: Atzin's general control is responsible for motion, sensor data, and communication with the surface.
2. Vision and Autonomous: it handles all image processing and autonomous driving logic.
3. Tooling Handler: it is a basic submodule that controls tools and actuators.
4. Client: the proprietary web interface that communicates the user with Atzin and displays its status.

C.INTERFACE

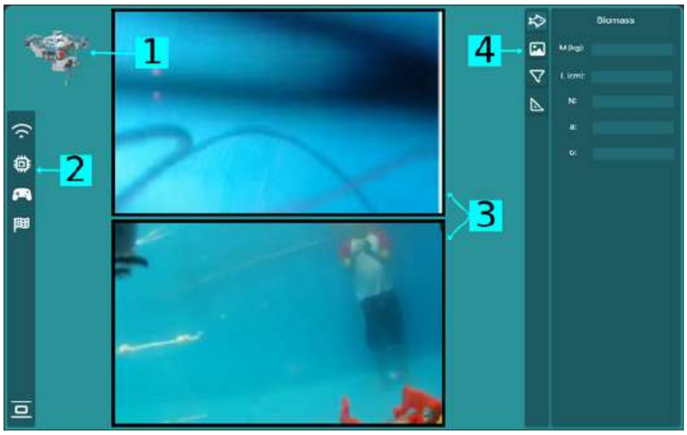


Fig. 29 "Interface"

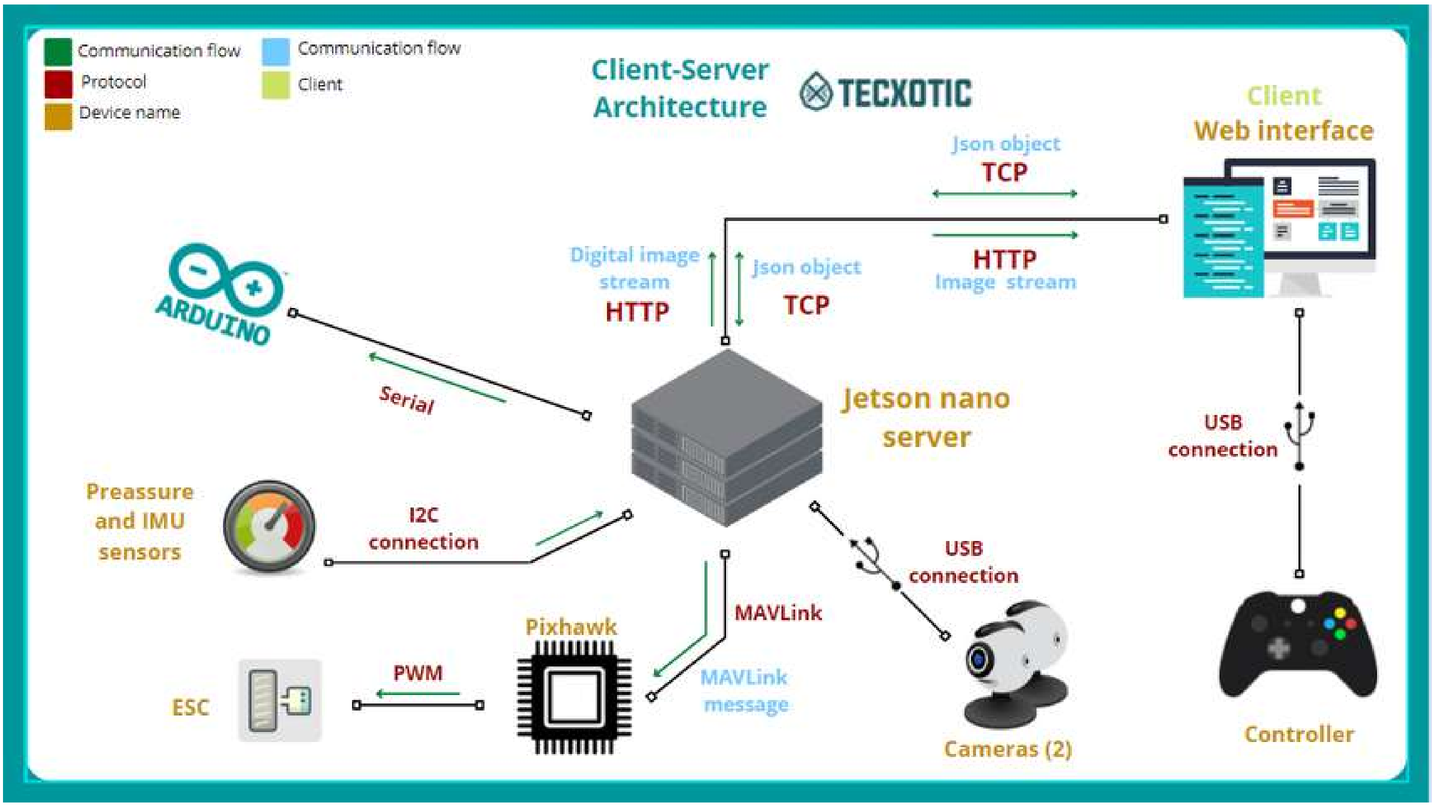


Fig. 28 "Communication Flow Chart"

The interface was designed to provide pilots with improved visibility of the images captured by the cameras and interaction with its functionalities. It is divided into four main sections (see Fig. 29):

1. **Orientation Miniature:** it displays the current physical orientation of Atzin
2. **Status Window:** it indicates system readiness, connection to the core module and pixhawk, and controller availability.
3. **Video Display:** it is the real-time video stream of two digital webcams connected to the vision and autonomous module (Fig. 30).
4. **Tooling:** it allows pilots to use tools (e. g. photomosaic, fish measurement, and grid map) and select the current driving mode (stabilized, controlled, or manual).

A monumental innovation in this edition is the ability to display preprocessed images with real-time filter adjustment to adapt to different environmental elements such as illumination level and water murkiness.

This year's main processor is the NVIDIA Jetson Nano board. A faster autonomous mode and real-time preprocessed video stream delivered to the interface is possible thanks to the reduced processing time as a result of the Cuda OpenCv build.

D. COMMUNICATION FLOW CHART

The NVIDIA Jetson Nano runs Ubuntu 20.04 LTS and JetPack V4.6 as its operating system. Two servers run in parallel inside, one responsible for sensors and movement control while the other handles vision and tooling modules with an API REST. TCP is used in order to ensure and protect the data transmission between devices.

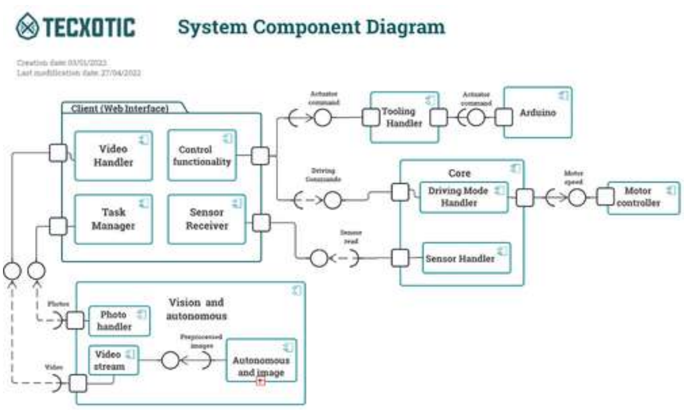


Fig. 30 "UML Component Diagram"

7. SOFTWARE TOOLING

Regarding the tooling, three main technologies are used:

- OpenCV: it filters videos and obtains the relative position of an element, which helped in the autonomous tasks 1.4 and 2.1 to position and move Atzin. Also, in task 2.3 OpenCV is used to calculate the size of fish by having a reference measure.
- AI RetinaNet: in task 2.2, RetinaNet was used to create a model to identify a "mort" or bank of "morts" in a video.
- Python Flask: it allows communication between frontend and backend, trigger processes, and display calculations. This was used for tasks 3.1 and 3.2.

8. MECHANICAL TOOLING

A. OVERVIEW

In order to simplify the operation and control of Atzin, no pneumatic system was used. This meant a paradigm shift in TecXotic's tool designs that traditionally used pneumatic actuators for activation. In addition, all the tools are located in the tool deck, which allows easy repairs or exchange if necessary. Five multifunctional tools were implemented and strategically distributed in the periphery of Atzin, providing high functionality and versatility.

B. HARD GRIPPER DESIGN

A three-finger multi-purpose gripper was strategically placed in Atzin's front tool deck. This configuration helps with tasks such as mort collection or seagrass grabbing. Its parts were 3D-printed using ABS, acrylic and Reynobond®, incorporating a modular design for easy replacement in case of failure or breakage.

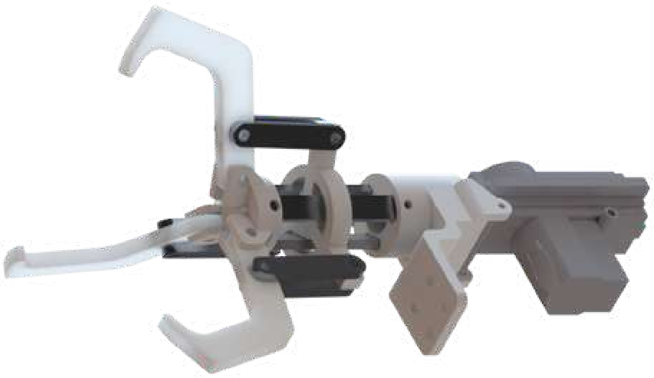


Fig. 31 "Hard Gripper"

C. SOFT GRIPPER DESIGN

Having a soft gripper provides Atzin the ability to grab delicate objects without harming them. This is considerably useful when Atzin is interacting with marine wildlife, given that many marine creatures are very sensitive to manipulation or interaction. Silicone composite was used which made it possible to reuse and improve the design of the gripper for Atzin.

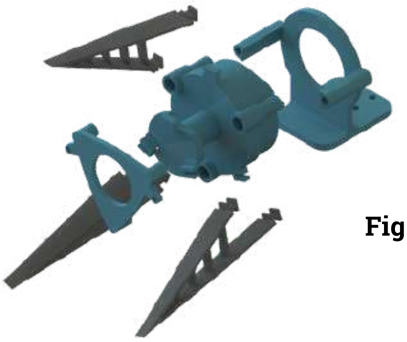


Fig. 32 "Atzin's Soft Gripper"

Fig. 33 "Kolop's Soft Gripper"

D. DOUBLE JAW GRIPPER DESIGN

This gripper was designed with two degrees of freedom: clamping and rotating around the neutral axis. The gripper has two jaws with an interlocking system for a complete grip. Although it was 3D-printed in PLA and ABS, all parts were designed using DFM guidelines for injection molding while CNC machinery mass production followed DFA guidelines.

For example, the gripper uses snap-fit joints instead of machine screws to decrease assembly time and the number of parts.

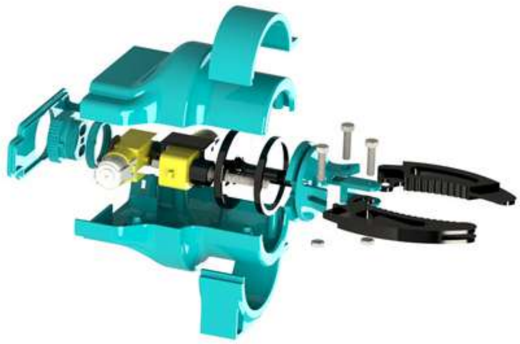


Fig. 34 "Double Jaw Gripper"

E. PIN EJECTOR DESIGN

Located at the front tool deck and powered by a 9.0 V DC motor, this system consists of a main body made out of 3D printed ABS parts. A rotating head was designed with multiple magnets attached using screws. The principle behind this design was to use the properties of magnetism and the considerable rotating speed that can be reached with relative ease in order to hold and extract the metallic pins from the required areas.

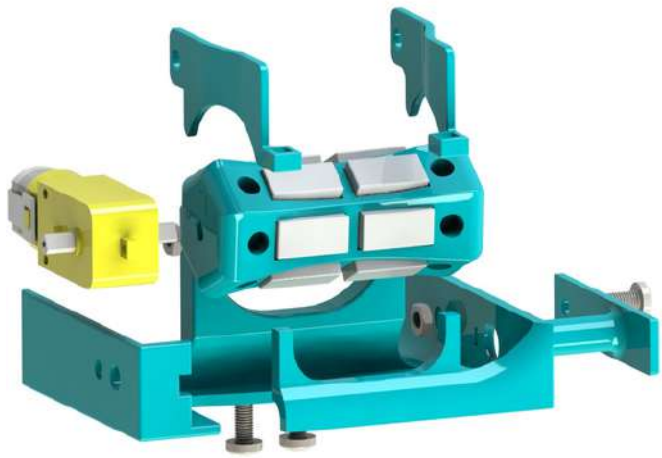


Fig. 35 "Pin Ejector"

F.DOUBLE PIN TRAP

Two powerful magnets attached to Atzin's right side make retrieving metallic pins an efficient and fast procedure, the size of such magnets guarantees a successful completion in almost every attempt with no extra maneuvering than getting close to the target, this system also works with smaller metallic parts which diversifies its applications in a real environment.

Fig. 36 "Double Pin Trap"

G. VISION SYSTEM

A total of seven cameras were implemented, consisting of two digital cameras and five PAL 170° analog cameras. These cameras are directly connected to a DVR that permits multi-camera vision fully scalable up to even seven analog cameras.. Additionally, the cameras are multidirectional due to the brackets which hold them in place. This phenomenal scalability makes Atzin capable of complete 360° peripheral vision.

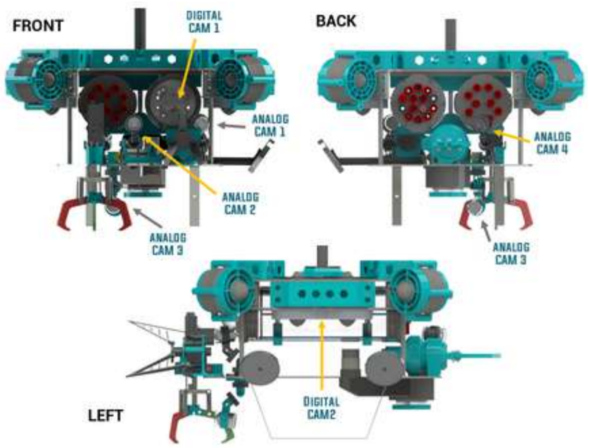


Fig. 37 "Atzin's Digital & Analog Camera Placement"

9.FLOAT (NON-ROV DEVICE)

A. DESIGN PROCESS

TecXotic's float device was designed and manufactured following the SMW philosophy. Small as it can be without losing functionality, easy to disassemble and swap components, all without losing the possibility for future improvements or modifications regarding the missions performed.

The main body consists of a Blue Robotics® 4-inch enclosure. It is used for its transparency property, allowing a quick visual assessment of the components inside. In addition, its reliability has been tested in the different applications TecXotic has used this component in.

Custom Nylamid caps with o-rings as seals were designed and manufactured. These create a waterproof seal with the enclosure, as well as adding weight to reach a neutral buoyancy state.

The final dimensions of the floating are 400.0 mm height, 127.0 diameter of the main body, and 260.0 mm diameter considering the stabilizer.

Fig. 38 "GO-BGC Non-ROV Device"

B. BUOYANCY ENGINE

The buoyancy engine consists of a membrane that inflates and deflates, changing the overall volume of the float. Therefore, the density decreases or increases, allowing Atzin to ascend and descend.

C. ELECTRONICS

Inside the cylinder, an air pump and a solenoid valve make up the buoyancy engine; a Blue Robotics® Bar30 Depth sensor is used to determine the depth of the float. Other sensors such as a gyroscope and accelerometer are part of the processing unit.

To control the pump and solenoid valve, based on the sensor's readings, a Control Space AI® Node IO® was used. In parallel, this works as an access point with an embedded web page from which the ground station can connect, obtain telemetry from the float, and start the immersion process.

D. BATTERY CONSIDERATIONS

Eight AA batteries inside the float are used to power the float. Connected in series, this battery bank has a total output of 9.0 V with enough energy to operate all sensors, the logic board, and other components like the air pumps and LED indicators.

E. ALTERNATIVES CONSIDERED

The buoyancy engine worked with an endcap moving inside the enclosure in a piston configuration, displacing air and deforming the membrane covering one end, increasing or decreasing the total volume.

A second idea following the piston configuration was instead of having a membrane in one end, allowing the water to flow through and change the overall volume having the same effect of dynamic buoyancy.

10. COMPANY ORGANIZATION AND ASSIGNMENTS

TecXotic is divided into four main areas: Design, Electronics, Software, and Corporate Responsibility, each one with an Area Leader. This division allows a focused workflow while simplifying communication between areas.

With respect to last year, the number of areas was reduced thanks to the involvement of all into the documentation process, each one assigning collaborators to this task. This means that the information displayed is first-hand acquired and increases the quality of the documentation process.

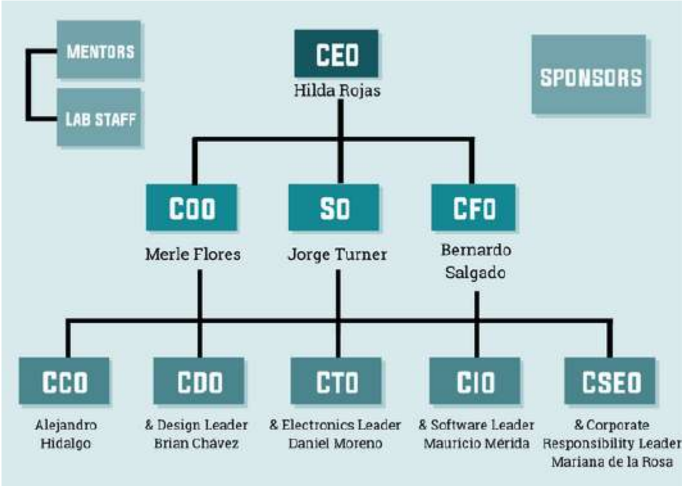


Fig. 39 "Company Organization"

Each Area Leader has a group of Supervisors that manage work distribution, decision making and deliverables approval, but if necessary, ultimately dependent on the CEO.

A. PROJECT MANAGEMENT:

This year, the company adopted the SCRUM framework in order to manage the design and manufacture of Atzin and its previous iterations. This framework allows agile processes involving collaborative work through incremental development strategies and involvement of every collaborator by creating autonomous teams that focus on delivering the greatest value of each task.

This framework was easily adopted by the different work teams since various collaborators are certified in SCRUM Fundamentals.

In the initial phase a workflow was established and possible risks and obstacles were identified. To facilitate the sprint management, five work teams were established with their respective leader.

To obtain an homogeneous integration between teams, two weekly meetings were held in order to update the status of the tasks, report incidents, and define their mitigation.

B. WORKFLOW

The SCRUM framework allows all collaborators to be informed about tasks nearing necessary completion and their correct assignment, while supervisors can give continuity to each employee. Recurring meetings are held, being structured and concise.

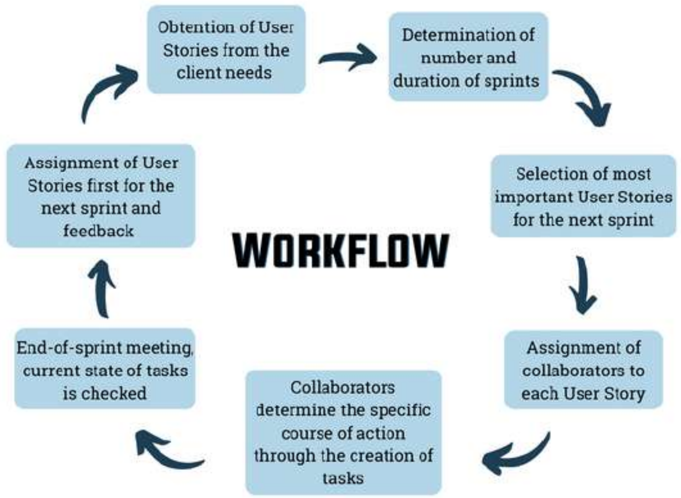


Fig. 40 "Workflow Diagram"

C. COLLABORATIVE WORKSPACE

ClickUp was chosen as the platform for managing the project, granting access to the collaborators in every area. One ClickUp project was generated for each area, giving easy access to the individual and group-oriented tasks to every collaborator. This allows quick communication between collaborators, facilitates the work assignment for supervisors, and keeps track of the completion of every User Story involved in the project.

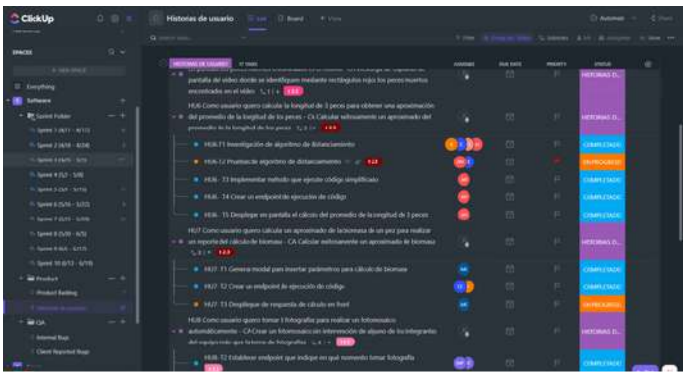


Fig. 41 "TecXotic's Click-Up Workspace"

Moreover, the platform Zoom Cloud Meetings was used for virtual meetings and remote work during and after the Covid-19 pandemic's peak. This provided an important way of communication that kept the company moving forward constantly while adapting to the different circumstances surrounding every collaborator, with utmost consideration of safety and government indications.

Another important part of TecXotic's work methodology is taking advantage of the knowledge and experience generated in past years, using the platform Google Drive as a repository and TecXotic's knowledge hub.

D. CODE MANAGEMENT

During the development of the project in software, GitHub was selected for project storage and an adequate version control system, allowing testing and corrections. Another important aspect is the use of branch functions, which allows each collaborator to work in their task without affecting the main code until testings are completed and the work is merged, generating a fluid, understandable, and organized final result.

F. PROJECT SCHEDULE

As it has been mentioned, the incremental approach of SCRUM through the use of sprints implies that there is no need for the creation of other diagrams like Gantt Charts, which have the disadvantage of necessary updates or even be remade in case of a mayor change or delay in the development process, having near zero flexibility.

At the beginning of the season, the duration and number of sprints was set by the department leaders considering the User Stories involving each department and the completion deadlines of the project considering the experience of the team members and the difficulty of the tasks. As an example, for the second half of the season, the Software Department determined ten sprints, with standard one-week duration to complete their 12 User Stories, assigning collaborators in each sprint depending on their capabilities to complete them on time.

11. Budget and Cost Planning

	Description	Type	Value	Category Total	Budget
Thrusters	T100 Thruster & T200 Thruster from Blue Robotics	Re-used	$400.00	$1,510.85	$700.00
	T200 Thruster from Blue Robotics	Purchased	$400.00		
	T200 Thruster from Blue Robotics	Donated	$400.00		
	Electronic speed controller from Blue Robotics	Re-used	$288.00		
	3D printed guards (Done by ITESM lab)	Donated	$22.85		
Mechanical Structure	Reynobond Sheets	Donated	$86.47	$736.87	$218.70
	Aluminum Screed	Purchased	$15.00		
	Aluminum Rod	Purchased	$87.20		
	3D-Printed tool pieces and frame parts	Purchased	$34.30		
	100 stainless steel screws	Purchased	$2.50		
	Brass threaded inserts	Purchased	$0.70		
	Enclosures (Acrylic tube, end cap, Flange caps, o-rings, and cable penetrators.)	Re-used	$431.70		
	Enclosures (O-rings, cable penetrators, and silicone lubricant.)	Purchased	$79.00		
Tether	Tether Nylon Sleeve	Re-used	$57.15	$165.85	$63.00
	Ethernet cable (communication with Nvidia Jetson Nano)	Re-used	$13.00		
	Power supply wire	Re-used	$25.70		
	Camera communication cable (20 m)	Re-used	$7.00		
	Little fuse 30 A	Purchased	$57.00		
	Anderson Power connector (To main point of connection)	Purchased	$6		
Electronic Components	Voltage regulator 6-55 V	Re-used	$25.37	$273.36	$42.85
	Mini560 Step Down DC-DC Converter Voltage Buck Power Module	Purchased	$6.00		
	Arduino Nano	Re-used	$9.00		
	H bridge L298	Re-used	$7.14		
	Wires and Connectors	Re-used	$15.00		
	CUAV Pixhawk PX4 Flight Controller	Re-used	$166.00		
	Anderson Power connector (To ESC's)	Purchased	$30.00		
	Fuse 5 A (To protect Nvidia Jetson Nano)	Purchased	$1.50		
	Geared Motor	Purchased	$5.35		
	Humidity and Temperature Sensor DHT11	Re-used	$8.00		
Atzin Computer Control	Nvidia Jetson Nano (main control operations and image processing)	Purchased	$666.00	$2,451.00	$900.00
	Bar02 High-Resolution 10 m Depth/Pressure Sensor	Purchased	$75.00		
	IMU Mpu 6050 (Accelerometers for Autonomous)	Purchased	$5.00		
	Logitech Webcam (To control vehicle)	Donated	$67.00		
	Logitech Webcam	Re-used	$67.00		
	Monitor (Display shows interface, connection with Atzin, and data)	Re-used	$1,571.00		
Control Box	Case	Re-used	$80	$322	$66.66
	Flat TV (Displays video)	Donated	$160.00		
	Control DualShock PlayStation 4	Purchased	$66.66		
	Connections	Re-used	$15		
Cameras	PCB's (To connection into enclosure)	Donated	N/A	$60.70	$60.70
	Tangxi Mini	Purchased	$60.70		

	Category	Description	Amount (USD)
INCOME	University Funding	Tecnológico de Monterrey	$5,000.00
	Team Fundraising	TecXotic team collaborators	$4,670.00
	Sponsoring Fundraising	booko pro, Wurth, Notaría 11, INOFLEX, SPACE AI INC	$8,548.00

Total Cost	$5,974.29
Total Re-used and Donated	$3,922.38
Travel and Transport	$14,250.00
Total Budget Allocated	$2,051.91
Cash Income & Foundraising	$18,218.00
Balance	-$45.62

Fig. 42 "TecXotic's Budget and Cost Planning"

TecXotic emphasized reutilizing all parts and components that were in good condition through the creation of an inventory, allowing the budget to focus on the acquisition of new pieces to improve Atzin based on past ROV editions. This year's budget was designed at the beginning of the season considering last year's expenses and the aforementioned inventory.

TecXotic wants to thank its home institution, Tecnológico de Monterrey, for being the company's main financial support, as well as the sponsors and donors that have provided funds for materials and aligerating travel expenses (since these run in account of the collaborators).

12. TESTING AND TROUBLESHOOTING

Testing began with digital simulations, wherein digital design was imperative to reduce time and waste during prototyping. After the design was approved the model was first built on MDF panels to understand how structurally resistant it is while looking to achieve strategic design goals, easy assembly, zero mechanical interferences, good component design, and tolerances. These prototypes provide better comprehension of Atzin's real underwater behavior, which made possible correct weight distribution when adding the front tool deck and all of its tool components.

13.CONCLUSIONS:

A. RESULTS

Atzin is the evolution of Kolop, the ROV that took TecXotic to the undisputed leagues of underwater robotics. Its development followed a meticulous and ambitious design, manufacturing, and testing process. The company was able to materialize the lessons learned in engineering solutions that surpass the challenges of 2022. All improvements are based on measurements, calculations, and tests that support that Atzin is a vastly superior ROV.

B. CHALLENGES

This year's recruitment process was one of the greatest challenges Tecxotic has faced. TecXotic's collaborators have a great deal of experience in robotics and competitions, but fresh ideas and enthusiastic spirits with plenty of motivation were needed.

Thus, the company started to outline a more professional recruitment process with technical and theoretical standards that candidates had to meet to become part of the project.

Unfortunately, this process was interrupted with the pandemic restrictions established nationally due to Covid-19. Nonetheless, TecXotic's workflow and protocols were succesfully restructured during the first half of the season.

C. FUTURE IMPROVEMENTS

TecXotic is constantly looking for innovation and improvements in every department. Therefore, the company is proud to maintain the philosophy that has allowed exponential growth year after year: **keeping up with times searching for innovation and incorporating simplicity into design.** Another important aspect is adopting the use of new technologies, scientific breakthroughs, and discoveries to share our learning and apply all this knowledge, making the best possible use of the resources available.

Furthermore, the company will strengthen its logistic operations, task assignments, and communication for better project management looking for ways to optimize the ROV's design for the next seasons.

D. LESSONS LEARNED AND SKILLS GAINED

This year was TecXotic's first formal recruitment process and, as a result, 55 new collaborators were hired. We needed to do this, so many people wanted to form part of

TecXotic after we triumphed the Mexican flag as part of the top three teams.

The outcome of the new recruitment process on the company's performance was highly positive, as the new collaborators have been exemplary, enthusiastic and goal-oriented.

Likewise, we never could have predicted the incredible results we experienced, as it is shown in Fig.43.

Having even more collaborators than last year emphasized that we did something right. That all those hours spent watching the sun disappear and break down while working are

CRITERIA	KOLOP	ATZIN	GOAL	RESULT	GA
Overall Width	0.48 m	0.54 m	▼	▲ 12.5 %	NA
Overall Length	0.62 m	0.69 m	▼	▲ 11.2 %	NA
Overall Height	0.38 m	0.36 m	▼	▼ 5.0 %	A
Envelope Volume	0.11 m3	0.13 m3	▼	▲ 18.0 %	NA
Free Space Volume	420 cm3	850 cm3	▲	▲ 101.0%	A
Tether length	20 m	20 m	-	-	NC
ROV Mass	15.7 Kg	13.6 Kg	▼	▼ 13.4 %	A
Tether Mass	3.8 kg	3.2 kg	▼	▼ 16.0%	A
# Modular Floats	5	56	▲	▲ 1120%	A
Floats Max Bouyancy	15.3 N	17.1 N	▲	▲ 11.1%	A
# ROV Parts	146	122	▼	▼ 16.0 %	A
# ROV Tools	5	5	-	-	NC
# Diff. nuts & bolts	12	4	▼	▼ 66.6 %	A
Horizontal Thrust	58.8 N	58.8 N	-	-	NC
Vertical Thrust	44.1 N	58.8 N	▲	▲ 33.3 %	A
Horizontal Speed	0.53 m/s	0.67 m/s	▲	▲ 17.0%	A
Vertical Speed	0.31 m/s	0.55 m/s	▲	▲ 46.0%	A
Degrees of Freedom	4	4	-	-	NC
Power Consumption	289.2 W	223.6 W	▼	▼ 22.6%	A

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

Fig. 43 " Atzin's physical parameters and accomplishments in comparison to Kolop ROV"

reaching someone, somewhere. The number of collaborators did pose a new challenge. Questions stormed us, "How are we going to work together? How are we going to reach every single member of TecXotic? To make them feel welcome, part of a new family?" And that, when it is time to leave, we know with full confidence that a better, capable person walks out of the workshop.

TecXotic was merely a wayward dream back in 2015. To put it simply, it was a crazy idea to be the first Latin American team in the history of the MATE ROV International Competition to participate. However, since then, many generations of engineering and high school students were inspired by the shared passion for underwater robotics. TecXotic is not just a company that develops underwater robotics, TecXotic is about dreams. About bringing impassioned thinkers together, sharing knowledge and inspiring new generations, and about believing that technology can be used to create a better future for all living beings. We believe that we have to "Create the ocean we need, for the future we want", because if you truly care to create something that preserves our planet Earth, you will always win.

Every year a more innovative ROV is developed, new technologies are implemented and new challenges are overcome. But more importantly, every year the same conclusion is reached: dreams are possible. MATE ROV Competition will always be more than a robotics competition, it is a dream factory, a breaking point for those whose dreams reach the boundless sky and the untold depths of the ocean itself.

E. ACKNOWLEDGEMENTS

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

MATE Center & Marine Technology Society
- For sponsoring the 2022 International Competition and inspiring us to create "The ocean we need, for the future we want"

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Tecnológico de Monterrey, Campus Cuernavaca

- **Erika Hernández, Mrs.** IKTAN Roving Team and Storyteller
- **Abel Angelina, Mr.** Media Lab Coordinator
- **Zazil Loewe, B.A.** Communication Leader
- **Ignacio Merlín, B.A.** Maker Space Coordinator (TecXotic HQ)
- **Carlos Ortega, B.A.** Mechatronics Lab Coordinator
- **Alfredo Nava, B.A.** Manufacturing Lab Coordinator
- **Salvador Fuentes, Mr.** Applied Engineering Center Coordinator
- **Antonio Flores, Mr.** Campus Security Coordinator

- **Fernando Obispo, BA**
  Lebotics 5948 FIRST FRC Mentor
- **Ricardo Valera, MSc**
  Electronics Professor
- **Sergio Hernández, MSc**
  Computer Science Professor
- **IKTAN Roving**
  Team for NASA HERC
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- **Sandra Salgado,** Wurth
- **Hugo Salgado & Marcela Díaz,** Notaría 11
- **Anel Sandoval,** INOFLEX.
- **Diego Favarolo,** Space AI Inc.

F. REFERENCE

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.p

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