TECXOTIC

HECHO EN MEXICO

2021
TECHNICAL REPORT

Cuernavaca, Morelos, México

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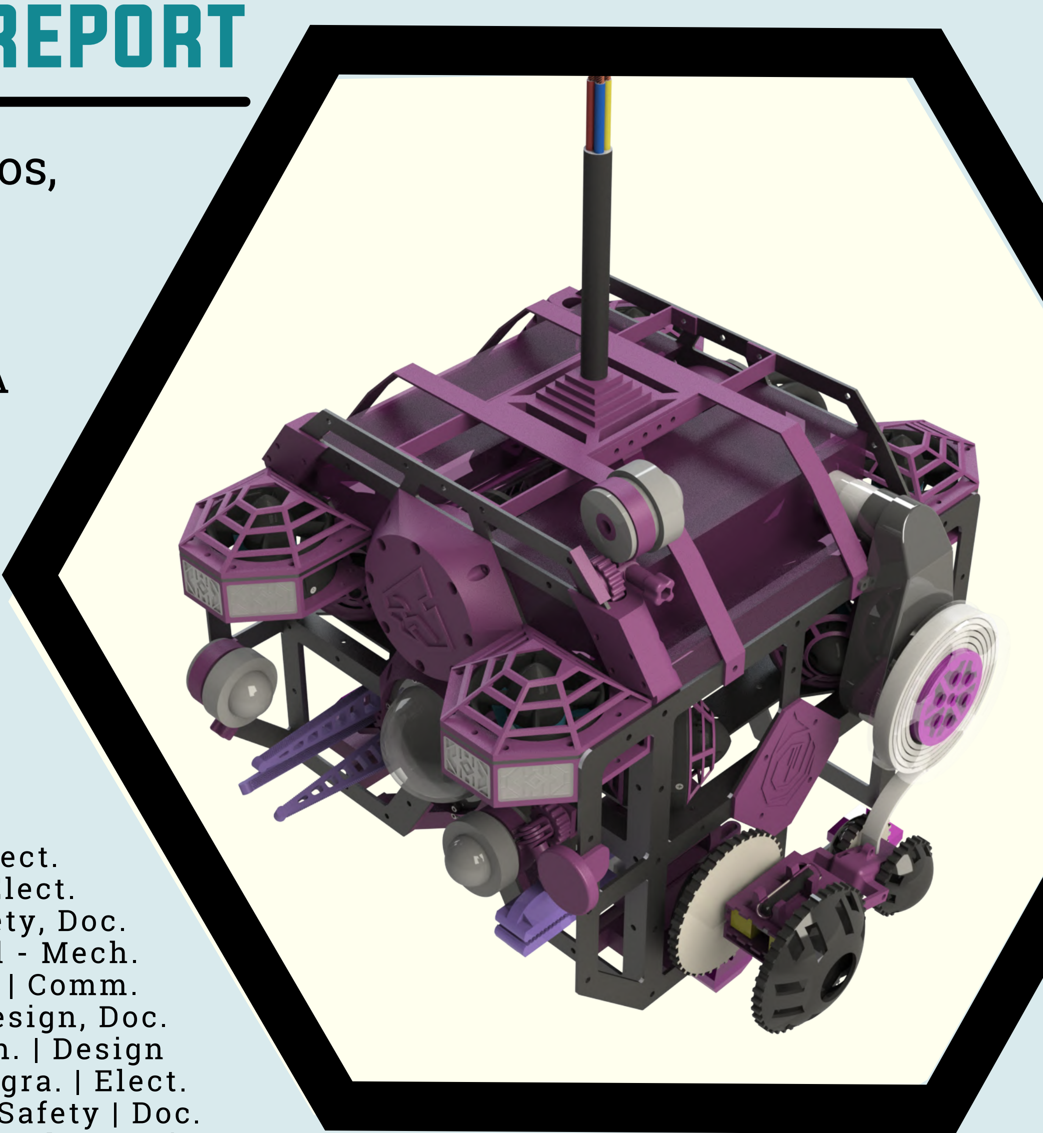

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Tecnológico de Monterrey

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Who makes it possible

0. GLOSSARY

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.

DESIGN AND MECHANICS

- RFP: Request for Proposals.
- SMW: Simple Modular Well-done.
- Reynobond: Aluminium Composite Panel.
- MDF: Medium Density Fibreboard.
- CNC:Computer Numerical Control.
- CAD: Computer Aided Design.
- CAE: Computer Aided Engineering.

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.

PROGRAMMING

- Art-Prompt (Ar-P): The graphical user interface that runs on a computer.
- TCP: Transmission Control Protocol.
- UDP: User Datagram Protocol.
- RFP: Request for Proposal.
- ESC: Electronic Speed Control.

1. ABSTRACT

Kolop is an underwater Remotely Operated Vehicle (ROV) designed to perform tasks without damaging the ecosystem and contributing to the decrease of plastic pollution in oceans, the assessment of coral reef health, and the maintenance of healthy waterways, among others. It has been specifically designed to work inside BOONE dam rivers and lakes, meeting the requirements presented this year by the Marine Advanced Technology Education (MATE).

TecXotic is a Mexican company formed by 27 professionals who brought their knowledge to different areas. From engineering to business, these areas include Design and Manufacturing, Electronics and Programming, Documentation and Logistics, as well as Marketing. Altogether, forming a powerful team that adds up for the best ROV possible.

Kolop is the newest addition to the TecXotic ROV family and the result of several months of development. Inherited experience from previous designs led to the development of improved tooling to successfully perform this year's challenges. The work in this project allowed us to understand the real-life issues that oceans and waterways face. High impact technology like Kolop is important to keep the world's waterways in good conditions.

This is all done by taking into consideration industry-based safety standards. So that, when Kolop is delivered to the customer, the safety protocols and the required specifications are met. Finally, Kolop is not just a university project, it is the inspiration by which we, young engineers, can learn and positively impact our environment.

INNOVATION AND SPECIAL FEATURES

Software:

- Propietary UI and telemetry
- Electronics
- Digital and analogic camera system
- Modular power system
- LED status indicator system

Design:

- Slim tensor relief
- frame wheels
- Soft adaptive gripper
- Gripper switch
- Easy conversion from 8 to 6 thrusters
- Three levels for tool placement
- Geometry and patterns inspired by Mexican folklore

Safety:

- Safety stickers
- SOPs
- New safety protocols and communication system
- Logistics
- A new and integral organizational structure
- An improved methodology for design and testing phases

2. SAFETY

A. SAFETY PHILOSOPHY

The safety of our collaborators, clients, and equipment is the number one priority for TecXotic. It creates comfortable working environments where collaborators can focus on the current task, improving the performance of all workforces.

Meeting international standards for safety regulations is just the beginning. All collaborators are committed to know and follow protocols in the lab or field. On that account, TecXotic looks for and promotes all collaborators' right to a safe, clean, and smart working environment. Having a peer-to-peer system, motivating all collaborators to follow the rules, to care for themselves and for each other. "TecXotic cares, because who cares, wins".

B. LABORATORY AND WORKSHOPS SAFETY PROTOCOLS

TecXotic has created a safety handbook for all collaborators to consult at all moments. It is constantly updated and informed. It contains safety information and protocols for different procedures, JSAs, SOPs, and Safety Data Sheets (SDS) for products used.

For example, when working with chemicals, gloves, a mask and glasses must be present to avoid damage from corrosion, irritation, or allergic reactions, and read the SDS for specific considerations of the product.
This year, a pandemic protocol and a health considerations section were also included.

To ensure a safe work environment for every collaborator, protocols are used for each working area. Personal protective equipment (PPE) is always available for collaborators to use. They are exhorted to always use the proper PPE according to the task they are performing, especially if power tools are involved.

All operations have a Job Safety Analysis (JSA) to prevent accidents, which must be read and acknowledged before being performed. Along the JSAs, we included in the Safety Handbook the Standard Operating Procedure (SOP) forms for different activities.

These SOPs detail a checklist before, during, and after the task. They establish the proper PPE, as well as a list of do's and don'ts of the activity. The collaborators are well trained in a three-phase program that prepares them to use the different tools and equipment in the lab to ensure proper use.

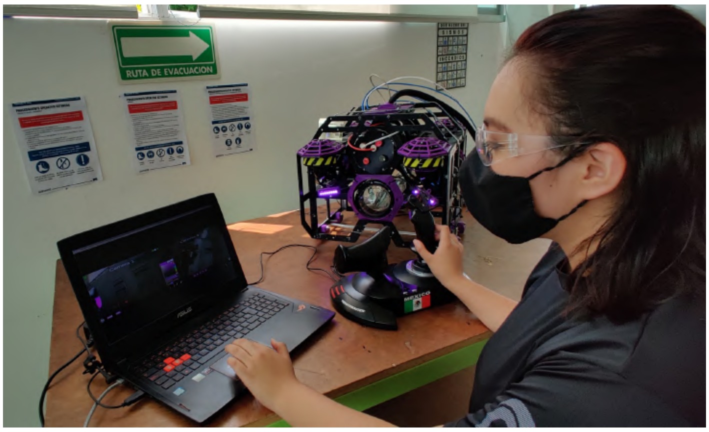


Fig.1 Electronic Testing SOP

C. ROV SAFETY PROTOCOLS

Regarding field operations, JSAs were designed to ensure the proper handling of Kolop. A safe pre-immersion and post-immersion checklist (Appendix I) reduces the probability of a malfunction during operation or transportation. This is very important because it guards the integrity of the operators and Kolop at all times.

D. SAFETY FEATURES

A variety of safety features has been implemented in mechanical, electrical, and software designs. Fuses for the main ROV and micro-ROV were calculated and placed, eliminating the risk of bursting components. A main Emergency Stop Button was placed in an accessible position for the operators at all times.

In case of malfunctioning, it stops the operation and prevents accidents. Also, Kolop has its own light flashing code, which gives visual information about its status. All thrusters are shrouded with a 3D printed PLA guard, blocking objects that could collide with the propellers.

A pressure release valve in each electronic enclosure allows Kolop to work smoothly at depths greater than what is stipulated by the Request for Proposal (RFP).

Each enclosure penetrator is sealed with loctite marine epoxy resin (for more information see Safety Handbook: SDS) and vacuum-tested to guarantee they have no weak spots, making a watertight entryway to the electronic enclosures. A series of sensors for pressure and humidity tracking will be constantly updated, indicating the operators the conditions and in case it is necessary, a safe shutdown. During the design phase, sharp edges were inspected, presenting a final product free of harm.

A new slim profile tensor release system was implemented this year, reducing interference when moving around, improving stability (no wheelies), and still allowing to redirect all tension of the tether. If the power is cut off or if reconnecting is not possible, all thrusters shut down and due to the slightly positive buoyancy of Kolop, an easy retrieval is possible from above the waterline, by pulling the cable line.

Safety stickers (Fig. 2) allow easy visualization of elements that could cause accidents. For effective communication, all collaborators know and use the safety operation signs and the vocabulary stated in the company's Safety Handbook.

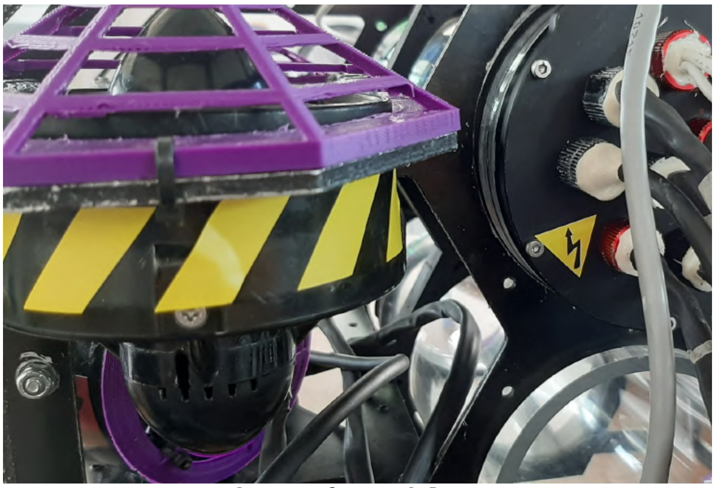


Fig. 2 Safety Stickers

3. DESIGN RATIONALE

Kolop is TecXotic´s most recent innovation in ROV manufacturing. The current design of Kolop is the expression of several years of testing and inherited experience. Criteria such as safety, size, weight, reliability, cost-effectiveness, ease of manufacture, and modular adaptability were implemented during all the design stages.

To fulfill the RFP requirements the stages of the design process consist of brainstorming ideas, sketching, 3D modeling, and manufacturing. Analyzing the strengths and shortcomings of previous designs allows the company to center its efforts on specific areas during design and prototyping.

TecXotic works under the Design Thinking philosophy, which allows to achieve suitable solutions through a creative iteration. Elements TecXotic implemented with the Design Thinking Methodology are:

- Empathize: understanding the problems according to the subject matter of the competition.
- Define: identify which are the tasks we want to focus on to be designed and tested first.
- Ideate: sketches and drawings were made using CAD (Computer-Aided Design)
- Prototype: develop a Minimum Viable Product (MVP) representative of each part or system.
- Test: trial and error during controlled operation.

The use of rapid prototyping and additive manufacturing techniques in several work areas led to the main innovations of this edition. Some advantages of this workflow are the reduction of testing and implementation time, it is also easier to make changes in the final product because of a modular design in all elements.

Fig. 3 Isometric photo of Kolop

A. DESIGN PHILOSOPHY

Year after year there's been a constant search to find more versatile, easy-to-assemble, and lightweight designs that are sought for more efficient travel and performance, that is why the SMW (Simple, Modular, and Well-done) methodology was adopted in every subsystem to facilitate the assembly with a holistic system approach.

SMW Simple
Modular
Well-done

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 and defects.

MODULAR: A modular design provides the capability to make repairs, adjustments, and updates to designs. Modularity requires the standardization of pieces, components, and assemblies. A modular design allows to strategically manufacture spare parts for the competition

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

TecXotic's Kolop aesthetic is inspired by the cultural legacy of our country, we designed some components based on geometric patterns and shapes of the Mexican folklore such as ancient pyramids and Mayan hieroglyphs.

4. MECHANICS

A. MECHANICAL OVERVIEW

Safety continues to be TecXotic´s top priority. Safety design protocols and operations were followed to ensure all aspects of the vehicle meet the safety standards stated by the RFP (Request For Proposal). This year's innovations were aimed at reducing size, weight and improving functionality. The increase in the use of 3D printing made it possible to achieve this goal.

B. FRAME

There are 3 main aspects considered during the frame design process: maneuverability, stability, and reliability. Its main function is to hold and preserve the critical components from environmental hazards during marine operations.

The inherited experience from previous models led to a complete frame redesign, focusing on having the highest available space for the tools, an acceptable speed underwater, and using the available space in an optimal way. The result is a balance of these goals: an ROV that meets the weights and size restrictions included in the RFP. It is also 20% smaller than the previous designs but with the same or even better performance.

It consists of a cubical shape made out of an Aluminium Composite Panel (Reynobond). Remarkable innovations for this model are the addition of wheels for displacement on plane surfaces, making certain tasks easier to complete; as well as the use of plates for tools on three different levels of Kolop.

Fig. 4 TecXotic's ROV Evolution

CRITERIA	GOAL (RFP)	RESULT	GA+
Overall width	<64 cm	42 cm	A
Overall Height	<64 cm	38 cm	A
Weight in air	<20 Kg	12.5 kg	A
Free space volume	>300 cm^3	420 c^3	NA

Table: Overall Weight and size of Kolop.
*GA = Grade of Achievement.
A = Achieved. NA = Not achieved.

Acrylic and Aluminium Composite Panel (Reynobond) were both considered as materials for the frame, while MDF (Medium-Density Fibreboard) for prototyping. All of which can be easily acquired and cut using the CNC router and the laser cutting machine.

After an analysis of mechanical properties, ease of manufacture and environmental impact, the material selected for the frame was Reynobond.

This material is known for its low expansion coefficient and exceptionally rigidiness, weighing 1.6 times less than pure aluminum. TecXotic reassures its commitment to promote manufacturing technologies with a low environmental impact, to achieve this goal, all the composite aluminum panels were re-used from material leftovers during the renovation work in our university campus.

Comparative of construction materials

	ACRYLIC	REYNOBOND
Panel Size	1.2 m x 2.4 m	1.25 m x 3.05 m
Thickness	5 mm	4 mm
Weight	6.32 kg/m^2	7.6 kg/m^2
Env. impact	Solid Panel	Composite Panel
	Not biodegradable! Very hard to recycle (reynobond needs Caustic soda)	
Mechanical properties	Weather resistant; Great electrical insulator; Light transmission rate = 92%	High degree of resistance to impact and torsion; Corrosion resistant
Cost USD)	$ 121	Donation*

*Reused material (96) USD is the commercial price

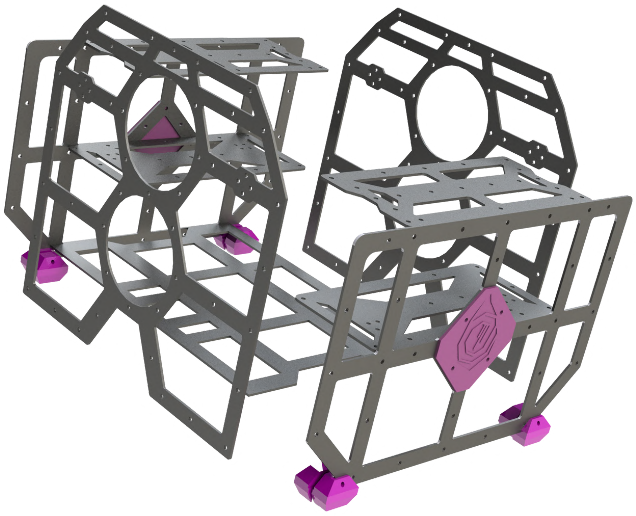


Fig. 5 Kolop's frame

Most of the frame uses planar parts that speed up the production and offer the possibility of using different materials without major design changes. Most of the frame parts are machined in the CNC router.

As part of the SMW philosophy, the use of symmetrical design is the best way to ensure that the center of mass of Kolop aligns geometrically with the model, for that reason the 2 four-inch acrylic cylinders are considered the center of the model and everything on its sides is symmetrical, thus the stability is guaranteed and the maneuverability is increased, allowing motion in sinuous environments, like the bottom of the sea or in coral reefs.

The electronic enclosure consists of two 4 inch acrylic cylinders that were reused from previous designs due to their reliability and excellent results.

In order to have greater mobility on flat surfaces, different supports have been implemented in the main base of the ROV, these supports have steel balls that function as wheels that facilitate the mobility of Kolop when it comes into contact with the bottom, being of great help when maneuvering the ROV in specific tasks, especially when wanting more precision to take starfish and coral samples, or even when removing plastic debris from the depths.

The use of CAD (Computer-Aided Design) & CAE (Computer-Aided Engineering) technology such as Solidworks, allowed TecXotic to find its center of mass, calculate mechanical properties, and simulations for design considerations.

The result is an ROV capable of maneuvering in tight environments such as coral reefs or places where the trash can easily accumulate (e.g. the coastline of a city or a commercial port) allowing an easier cleaning of the plastic pollution in the area.

C. HYRDODYNAMIC ANALYSIS

Fluid simulations were created before the manufacturing of Kolop with the purpose of having a suitable design for a correct operation on environmental conditions included in the RFP (Fig. 6 and Fig. 7).

To obtain accurate results, the conditions used are similar to those found in coral reefs. Resulting in 6 bar of pressure or depth up to 50m underwater, 301.15 °K, and water flow with a constant velocity of 0.3 m/s (average speed of Kolop underwater).

In all the cases, water flow behaves as a laminar flow and the flow's velocity keeps above 8% of its initial speed. Meaning that the movement of Kolop can't create turbulence that could affect delicate ecosystems like coral reefs allowing a better inspection of them.

D. PROPULSION LAYOUT

Kolop is equipped with 8 Blue Robotics underwater thrusters specially designed for marine purposes (2 T100 and 6 T200, T 200 is a revision of the T100 with an increased thrust from 2.36 kgf to 5.25 kgf and two modes of operation). All of them were reused from previous designs due to their excellent performance. They are highly reliable, adaptable, and size-convenient.

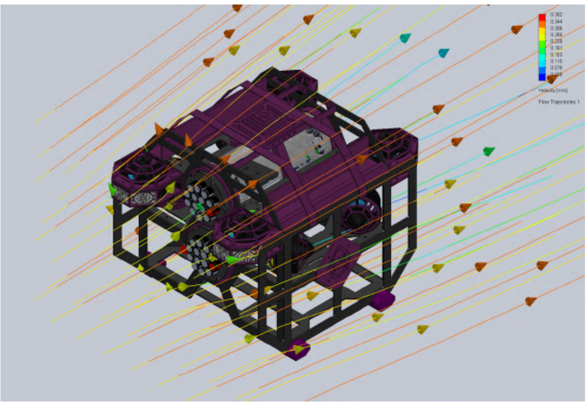


Fig. 6 Water flow direction. Solid Works Simulation

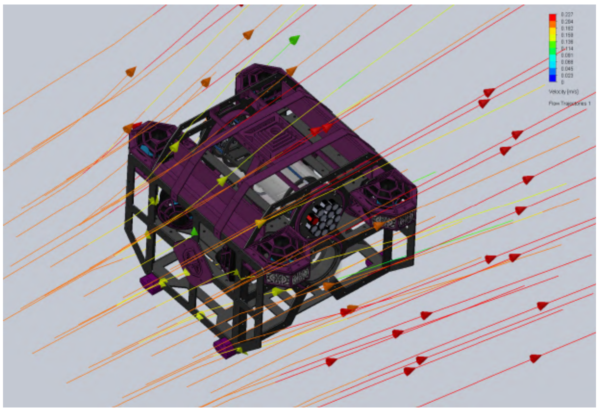


Fig. 7 Water flow direction. Solid Works Simulation

The unpredictable conditions in the environments of the mission such as turbulence, suspended objects, or narrow places on harbors or marinas are a huge concern for TecXotic. That's why one of Kolop’s special features and innovation is the interchangeability of the number of thrusters in case of thruster failure. An alternative thruster configuration is possible due to the modularity of the frame, being able to use either eight or six thrusters.

Kolop´s propulsion system allows motion in three perpendicular axes providing 6 degrees of freedom (Fig. 8). Motion around the heave axis is a priority due to the challenge of stability that demands four thrusters, where all the corners require the same height at the same moment to ensure stability.

The yaw is possible due to the combination of rotation and forward motion. The 4 T200 thrusters were mounted horizontally on each of the frame’s corners at an angle of 45°. The average speed of Kolop is 0.10 m/s, able to reach a depth of 2 meters in 10 seconds and rotational speed of 0.9 rad/s.

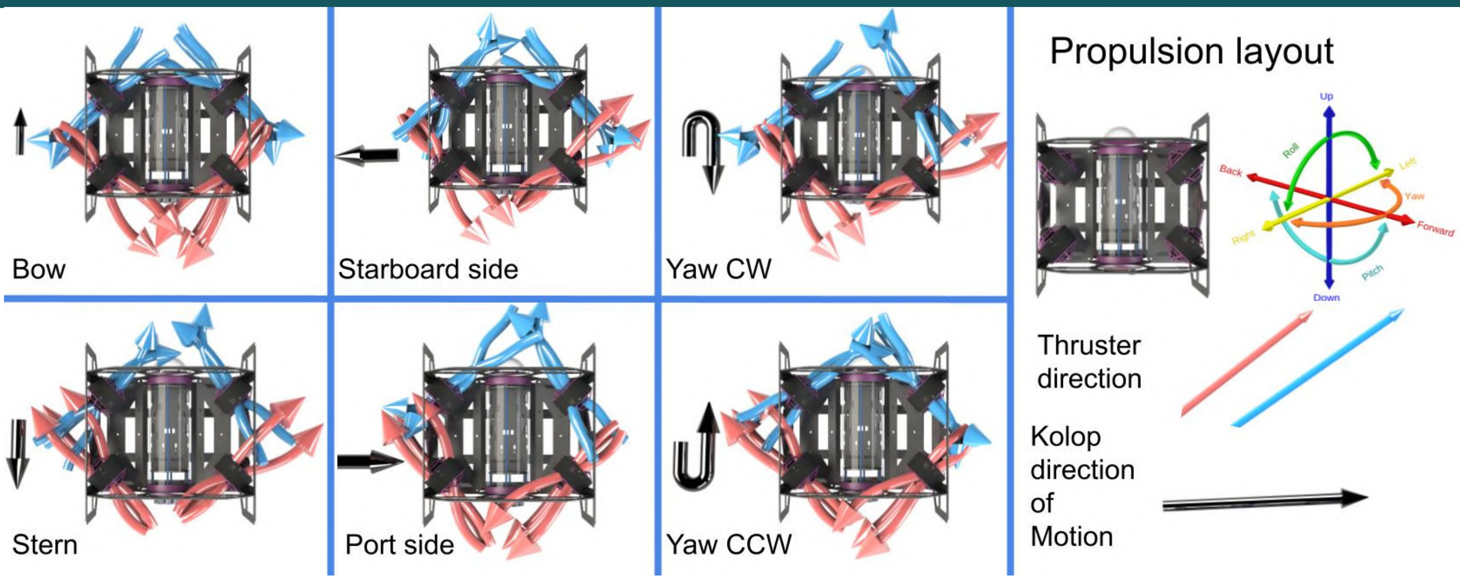


Fig. 8 Propulsion flow layout

E. ELECTRONIC ENCLOSURES

The electronic housing is split into two cylindrical acrylic containers by Blue Robotics (Watertight Enclosure for ROV 4" series). The affordability, reliability, and high configurability are the reasons why TecXotic decided to use these components versus developing from scratch.

Rated for depths up to 100m, the cast acrylic plastic tube provides the necessary space for the electronic components. Due to the translucent 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.

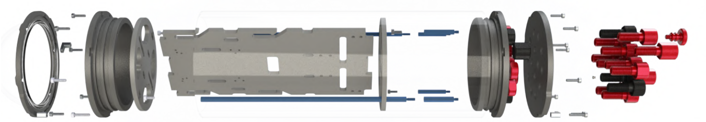


Fig. 9 Electronics cylinder enclosure

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 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 Kolop 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 enclosure penetrators. Due to the circular shape, the stress is distributed evenly along the cylinder avoiding shear stress in the corners as in the case of square enclosures.

Being able to visualize in low light conditions and being able to clearly discern the targets such as coral fragments or 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. The support is printed using 3D PLA filament.

F. BUOYANCY

The unpredictable conditions in environments such as rivers, lakes, or marinas at the moment of removing plastic pollution or mapping points of interest gave us an insight regarding how the buoyancy of Kolop should behave.

The buoyancy is the upwards force applied by any liquid to an object submerged in it because of pressure; the diagram shown below exhibits the forces involved (Fig. 10).

Having neutral to little positive floatability is good for safety, this prevents Kolop from getting stuck at the bottom if the motors fail. However, this floatability needs to be low because otherwise, the motors will need to use more power in order to move and submerge Kolop.

The design was made with this consideration, and every time a new version is made, a spreadsheet (Fig. 10) is used to calculate its buoyancy so weights or floats can be modified to adjust floatability.

It is important to align the center of mass and the buoyancy center in order to ensure the stability of Kolop, which is important to facilitate the use of tools and the successful completion of the tasks. To do so, not only should the mass be equilibrated on both sides of Kolop, but they also need to displace the same volume of liquid.

		Obtained from
Volume (m^3)	0.0158	SolidWorks
Liquid density (kg/m^3)	997	External data investigation
Buoyancy (N)	154.533006	$g\rho V$ (density and Volume from liquid)
ROV mass (kg)	15	Meassuring
ROV weight (N)	147.15	gm (ROV mass)
Floatability (N)	7.383006	$Buoyancy - W_{ROV}$
Buoyancy needed to achieve neutral bouyancy	-7.383006	

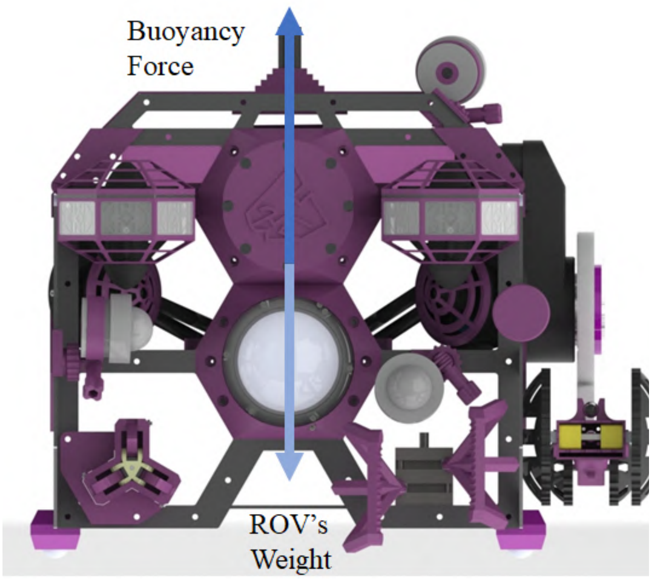


Fig. 10 Kolop's free body diagram and buoyancy chart

G. OMNIDIRECTIONAL CAMERA BRACKET

The operators' field of vision is one of the most important aspects during Kolop's navigation when performing different tasks such as cleaning plastic debris or mapping an area. Therefore, a support has been developed (Fig. 11), allowing the adjustment in the vision angle of the cameras, this mechanism allows a 360-degree rotation and a certain vertical tilt, using two degrees of freedom as a great advantage.

This is one of Kolop's special features and one of the most important innovations of this year because the design of this holder allows fixing any of the three cameras that Kolop has in any position of the main housing.

The parts that allow rotation are 3D printed with PLA filament, and the parts that cover and protect the cameras were manufactured with epoxy resin, selecting this material in order to reduce costs and at the same time ensuring optimum performance.

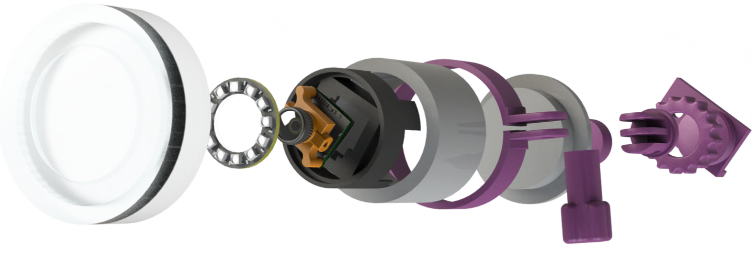


Fig. 11 Omnidirectional camera bracket

H. TENSOR RELEASE

The tensor release (Fig. 12) is centered at the top of Kolop, consisting of a 3D printed ball caster with a clamp/headband that presses the cable, so that, when pulling the cable, the ball caster stays in its place. This ball fits inside a little pyramid-like shape that is connected to the frame of the Kolop with graf nuts and screws, and when the tether is pulled, the force is redirected to the ball, then to the pyramid 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 the cable-free motion, which helps Kolop to maneuver easily when going through coral reefs.

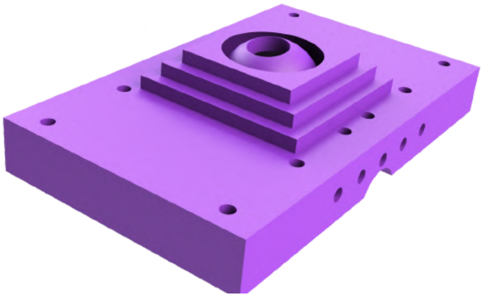


Fig. 12 Slim tensor relief

I. THRUSTER GUARDS

Thruster guards were designed and 3D printed using Solidworks. They were specifically designed to cover the thrusters preventing unwanted objects such as plastic parts or another form of aquatic life from colliding with the propellers.

The geometric patterns presented are inspired by Mayan geometry. These patterns were considered a divine language used for the understanding of mathematics and astronomy.

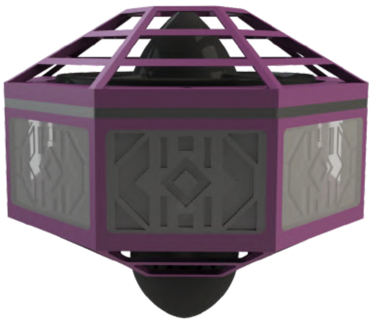


Fig. 13 Thruster guard

5. ELECTRONICS

A. ELECTRICAL OVERVIEW

The design of Kolop's electrical system was created focusing on SMW philosophy. Having a modular electrical system results effectively when testing different prototype tools and replacing electronic components. Creating a reliable and modular architecture that allows the modification of components with minor adjustments is essential.

This is why it is divided into 4 key sections allowing the communication between the operators and the ROV:

The Ground Control Unit (GCU) is located above the waterline where the operators are able to see and control all aspects of Kolop. The tether is the link between the GCU and the element below the waterline. The Thruster Control Enclosure(TCE) and the Main Control Enclosure (MCE) are strategically positioned at the center of the ROV and are responsible for controlling all actuators and sensors.

B. ABOVE WATERLINE ELECTRONICS

GROUND CONTROL UNIT (GCU):

The GCU is responsible for sending and receiving data from Kolop, displaying the cameras' stream, and TecXotic's new interface with all sensor data (main computer and input joysticks). It also controls the pneumatic grippers aboard (gripper manager made out of pneumatic valves and controls) and an emergency stop button that interrupts the power supply down the tether immediately, ensuring the operators and Kolop's safety.

C. WATERLINE TRANSITION

TETHER

The tether sends uninterrupted power and data from the GCU to the MCE and TCE where power conversion takes place, as well as pneumatic air to the grippers. It consists of two 12 AWG power cables, one 30A fuse within 30cm of the SB50 Anderson power connector, three analog camera system cables, a Cat 5e ethernet cable, and four pneumatic 4 mm hoses.

The end of the Tether connects to Tecxotic´s brand new 3D printed tensor relief system, which secures the connectors of the MCE and TCE. The whole length (18m) is covered by an expandable braided sleeve, reducing entanglement and protecting the tether from friction.

TETHER PROTOCOL

A completely defined protocol and system of safety signs and operations can be found in the Safety Handbook. These signs, words, and defined actions complement the immersion checklist allowing effective communication between the operators to ensure a safe operation.

Fig. 14 Tether division

D. BELOW WATERLINE ELECTRONICS

All cables entering the electronic enclosures must pass through either WE-006 6 mm or WE-007 8 mm aluminum penetrators with o-rings forming a tight seal. Inside the enclosure, desiccant silica gel bags are placed to absorb all moisture.

Compared to past editions, this year's innovation is the division of the electronics into two interconnected systems, having the thruster's control and the main control in two different cylinders (Fig. 15)

The connectors used on the enclosures are:

- Bullet connectors: used on the Electronic Speed Controller (ESC) output making each module replaceable, ensuring a proper connection, and eliminating faulty connections.
- Anderson powerpole connectors: used on the power supply cables, offering a higher current capacity, they are color-coded (live and neutral) and vibration resistant.
- Heat shrink soldering sleeve: A transparent heat shrinkable tube, with a wax waterproof ring on both sides and a tin ring in the middle.
- Lever Nut connector (PCT 213): A multiple 3-5 current splitter connector.

Electronic Testing and 3D Printing SOPs can be found in Tecxotics Safety Handbook.

E. THRUSTER CONTROL ENCLOSURE (TCE)

From the tether, 48V are delivered from two 6mm penetrators and connect in parallel with three Variable Step-Down DC-DC Buck (15A 200W). Two-step downs are configured with an output of 20V for greater efficiency (Fig. 18) connecting to 6 ESCs managing T200 thrusters.

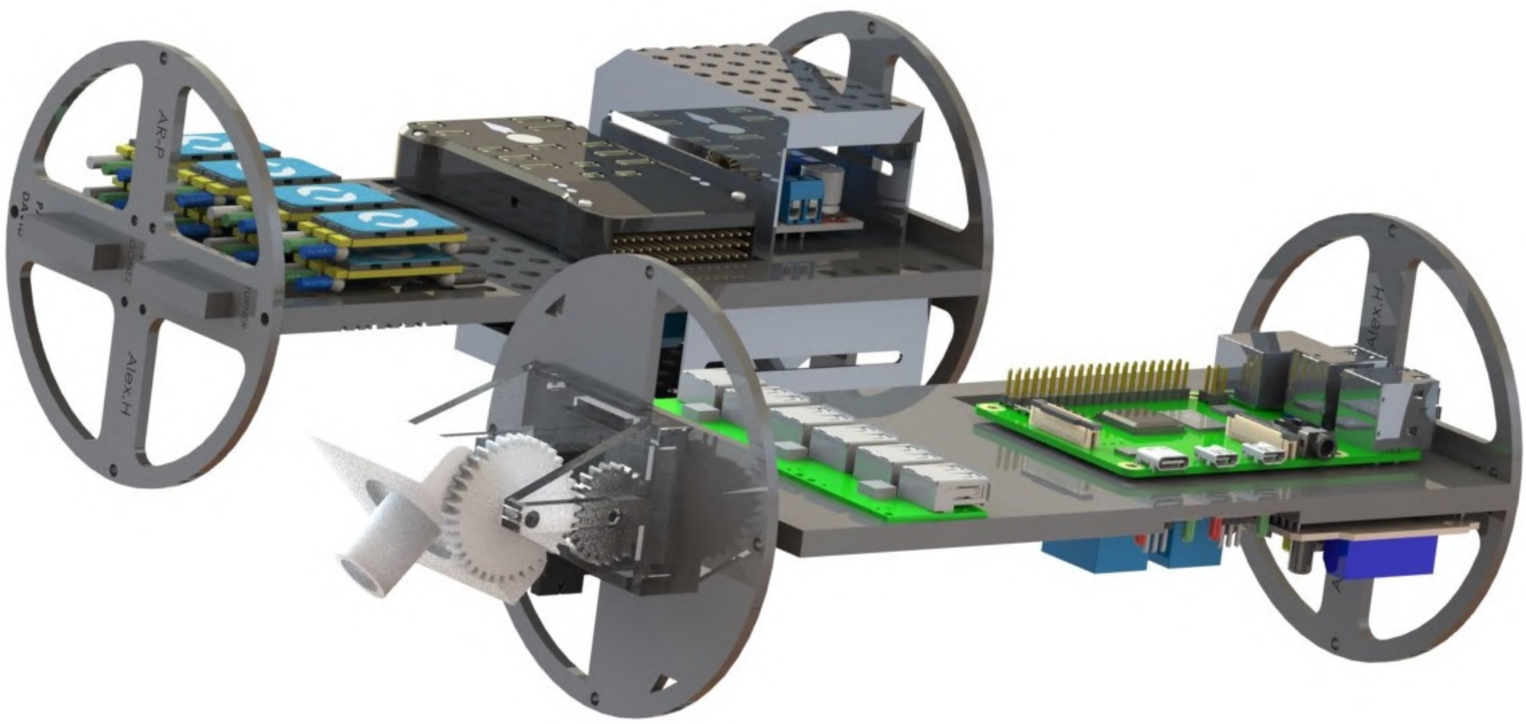


Fig. 15 Left to right TCE and MCE

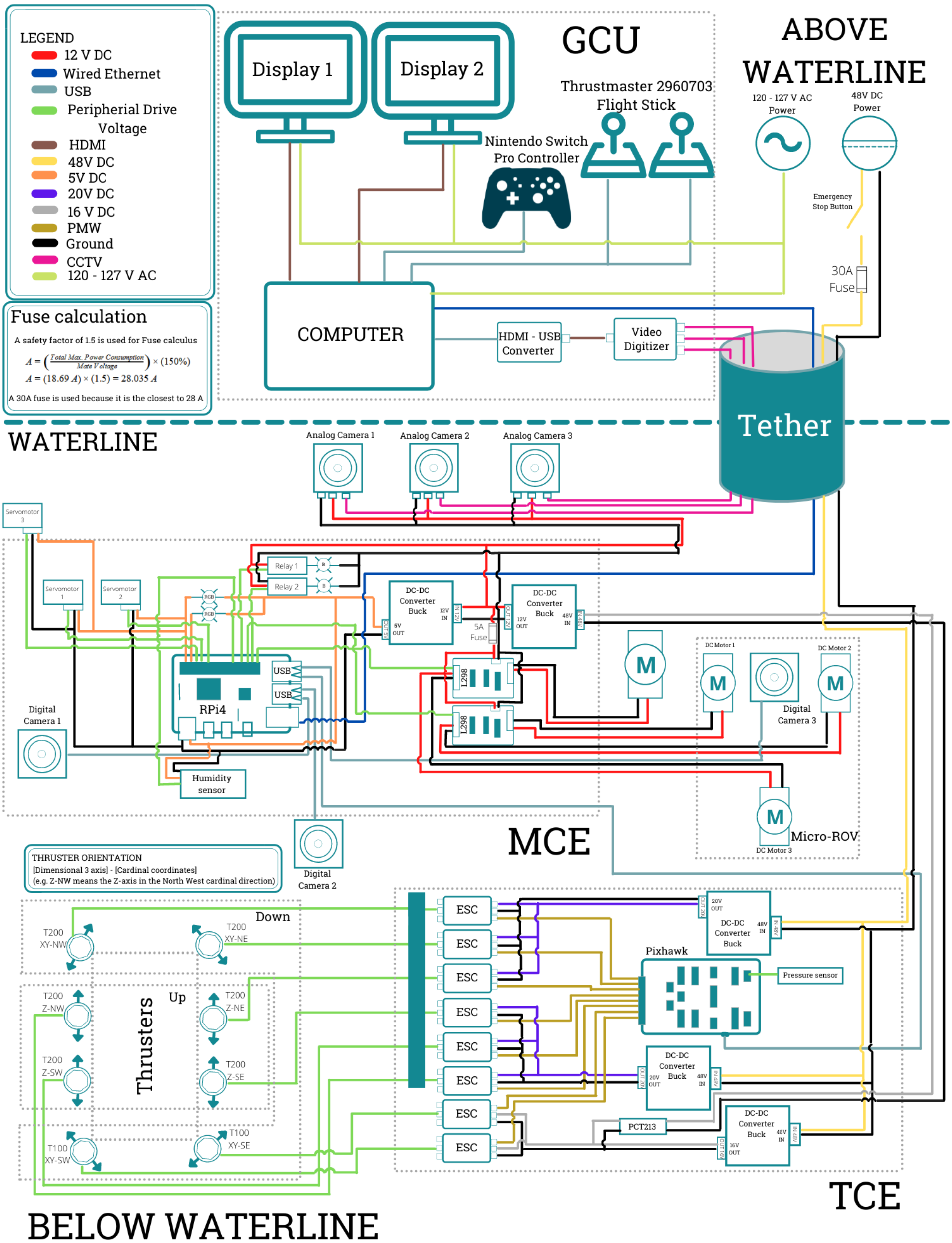


Fig. 16 Kolop's SID

DC-DC Converter 48 to 20V 200W Efficiency 94%	Qty	Volts (A)	Current (A)	Total Current (A)	Total Power (W)
T200- THRUSTER-R2-RP	3	20	1.7	**5.1**	**102**

DC-DC Converter 48 to 20V 200W Efficiency 94%	Qty	Volts (A)	Current (A)	Total Current (A)	Total Power (W)
T200- THRUSTER-R2-RP	3	20	1.7	**5.1**	**102**

DC-DC Converter 48 to 16V 200W Efficiency 94%	Qty	Volts (A)	Current (A)	Total Current (A)	Total Power (W)
T200- THRUSTER-R2-RP	2	16	1.1	**2.2**	**35.2**
DC-DC Converter 16 to 12V 200W Efficiency 94% 15A MAX					
Foxeer Predator FPV Analog Camera	2	12	0.05	0.1	1.2
Aqua Vu Underwater Analog Camera	1	12	0.05	0.05	0.6
H Bridge module L298	2	12	0.09	0.18	2.16
12 V Motor High Torque Gear Box	3	12	1.6	1.6	19.2
12 V Motor Gear Box	3	12	0.24	0.72	8.64
RGB LED STRIP	2	5	0.24	0.48	2.4
				3.13	**34.2**
DC-DC Converter 12 to 5V Efficiency 94%					
Raspberry Pi 4	1	5	0.6	0.6	3
Servomotor	3	5	0.2	0.6	3
WS2812B 5050 RGB LED Ring	2	5	0.24	0.48	2.4
DHT11 Humidity Sensor	1	5	0.001	0.001	0.005
Relay module	2	5	0.09	0.18	0.9
Digital USB Camera	2	5	0.15	0.3	1.5
Pixhawk	1	5	1	1	5
				3.161	**15.805**

	Total Current (A)	Total Power (W)
Whole ROV system*	**18.69**	**289.205**

Fig. 17 Kolop's power budget

The third one delivers 16V and connects to two T100 thrusters and their respective ESCs, and the MCE. Using 5 inexpensive Step-Downs instead of 1 single and more expensive Step-Down makes the power distribution modular. If one Step-Down fails, it can be switched without disturbing the power to the rest of the systems.

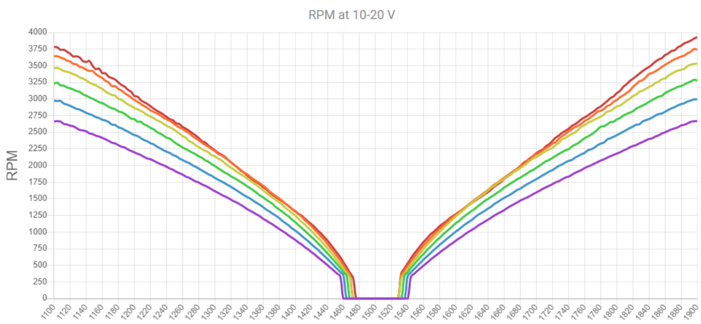


Fig. 18 T200 Efficiency curve. Red 20V

PIXHAWK

Kolop uses the Pixhawk as a controller since it allows easy and stable control for the brushless motors, sensors, and the MAVLink protocol integration with the Raspberry Pi 4. The Pixhawk manages the ESCs in the ROV through PWM signals and the pressure sensor with an I2C bus powered by 3.3V.

F. MAIN CONTROL ENCLOSURE (MCE)

The MCE receives 16V from the GCU. Inside the MCE, a Step-Down (DROK DR-US180076) reduces the voltage from 16 to 12, the same voltage in which the LED modules and the analog camera system work. A micro Step-Down 12V to 5V supplies the RPi 4. The RPi4 manages communication with the GCU, the Pixhawk, and the digital camera system, including the servo motor responsible for the camera tilt system (Fig. 15, MCE).

In this edition, interactive LED modules were included as a safety feature. They allow the operators to make a quick assessment of Kolop's status:

- Red: Kolop is not connected to the GCU.
- Orange: The Pixhawk is not connected to the RPi4 and the server communication.
- Green: Kolop is armed and ready to operate.

After a successful connection between Kolop and GCU, the operators can adjust the color values to better suit the lighting conditions.

6. SOFTWARE

A. PHILOSOPHY AND OVERVIEW

TecXotic's software philosophy is to develop and use modular subsystems that work independently from others, thus making a scalable and simple-to-use system.

This year's innovation is the completely new user interface design. It was made from scratch based on the client-server architecture. This architecture gives rise to data sharing, data processing, and data centralization, which guarantees data integrity.

B. COMMUNICATION FLOW CHART

The system starts from the idea to have a custom interface, easy to use and provides all needed information. It was made with Unity and C# as the main programming tools on Windows 10 as the operative system.

Kolop's user interface is named Art-Prompt (Ar-P) two words that describe important features of the system:

Art: Ar-P is an interface easy to read, and it follows minimalism as the style of art implemented in the development of visuals.

Prompt: refers to any system's readiness to perform a command. Since Ar-P is responsible for linking communication and sending instructions.

Ar-P connects to the server (RPi4) through TCP to send commands to Kolop and receives a video stream through UDP (Fig. 21). The use of TCP to send commands makes the system reliable, having an error-free response from Kolop, as well as to always have a full-duplex communication mode.

UDP enables to have in Ar-P a fast image from the camera sensors, this is the best approach to have a real-time camera system streaming from the server. This system will display the real status of each indicator and operators will respond accordingly. The commands are sent from the keyboard and two dual joysticks.

Ar-P has two displays, the left-side screen will display the camera and indicators of the primary driver, controlling roll, pitch, and yaw orientation of Kolop (Fig. 19); the right-side screen will display the camera view of R-Kolopito (micro-ROV) and the indicators for the secondary driver (Fig. 20).

Both drivers can change their camera view if needed. Having minimal visual art in the interface is useful for the operators to concentrate on the tasks and not get distracted by lots of indicators in just one display.

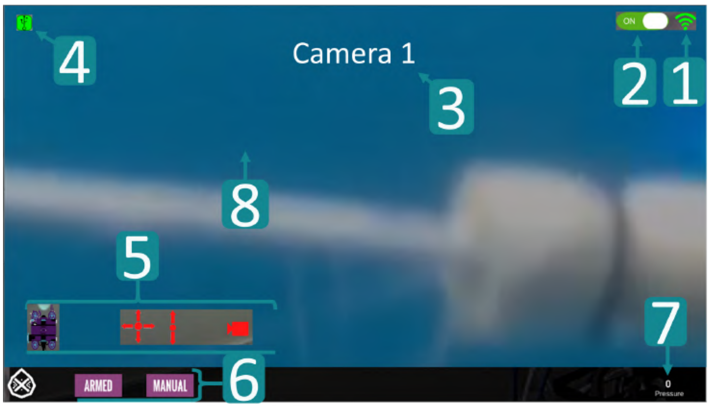


Fig. 19 Left side of the screen of Ar-P

1.- Indicator of the connection between Ar-P and the server
2.- Button that enables the connection between Ar-P and the server
3.- Indicator of the camera view
4.- Indicator of the connection state of the Pixhawk to the system.
5.- Indicator of the orientation and movement of the primary joystick
6.- Indicator of the state of the motors (armed/disarmed) and the flight mode settings
7.- Indicator reading of the pressure sensor
8.- Camera display

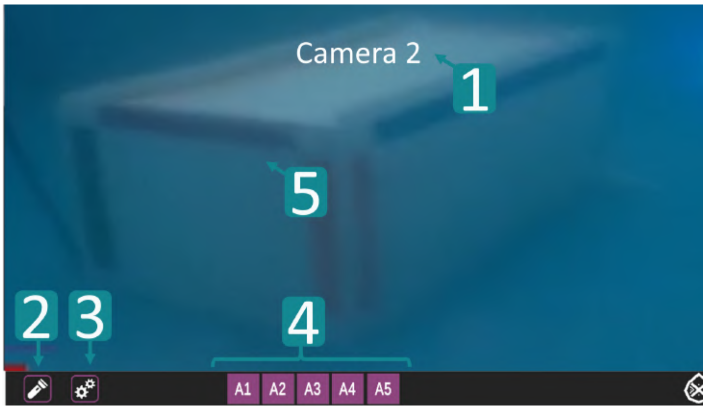


Fig. 20 Right side of the screen of Ar-P

1.- Indicator of the camera view
2.- Button that enables the settings of the LED lights (RGB selector)
3.- Button that enables the settings of the camera port, server IP address, and the PID constants for one of the autonomous tasks
4.- Indicator of the active and inactive agents created for the autonomous tasks
5.- Camera display

The camera system is composed of both analog and digital cameras. The server processes the digital cameras and starts a stream using the GStreamer framework. The analog cameras are connected directly to Ar-P with the help of a video converter.

This innovation of having both technologies for the camera system, allows a real-time video stream and to perform autonomous tasks (processed inside the server) at the same time.

The server is developed using Python as the main programming tool and runs on Ubuntu as the operative system in the RPi4. The server manages access to Ar-P receiving and sending data in JSON format. Once the server starts receiving data, it sends instructions to each electronic component such as sensors and controllers. For controlling the thrusters, the MAVLink protocol is used to communicate with the Pixhawk (see Fig. 3).

When Kolop is commanded to perform an autonomous task, OpenCV is used for image processing with the digital camera stream.

Fault tolerance implementations allow a stable system, the essential data in the connection settings is stored in JSON files, for reading ease, such as the streaming for the cameras over UDP, and IP address and port to start the server. In case some component in Kolop disconnects or stops working while being underwater, it doesn't affect the other components, the implementation ignores the malfunction and keeps working with no interruptions.

C. MANUAL CONTROL:

The manual control is composed of the primary and the secondary controllers. The first one will be managing the orientation of Kolop, the LED lights, the position of the main camera inside the MCE, and the view of the left side of the interface (Ar-P); the second one will activate and deactivate the autonomous control, the micro-ROV, and the camera views of the right side of the interface (Ar-P).

7. SOFTWARE TOOLING

A. AUTONOMOUS CONTROL

Kolop has three autonomous modes for specific tasks:

- Task 2.1 is programmed using OpenCV to recognize the blue lines, with a PID controller that keeps Kolop inside the limits and goes forward, mapping the coral reef and identifying points of interest.

- Task 2.2 with help of OpenCV, recognizes the differences in colors according to the position and size of the two coral reef images being compared.

- Task 3.4 using OpenCV and a custom algorithm, sorting and stitching the images (of the artificial coral reef) according to the color is possible. The algorithm crops each image to the edges of the box then recognizes the colors in the edges and sorts the pictures taken to create the photomosaic. This algorithm allows the driver to take the pictures in no specific order.

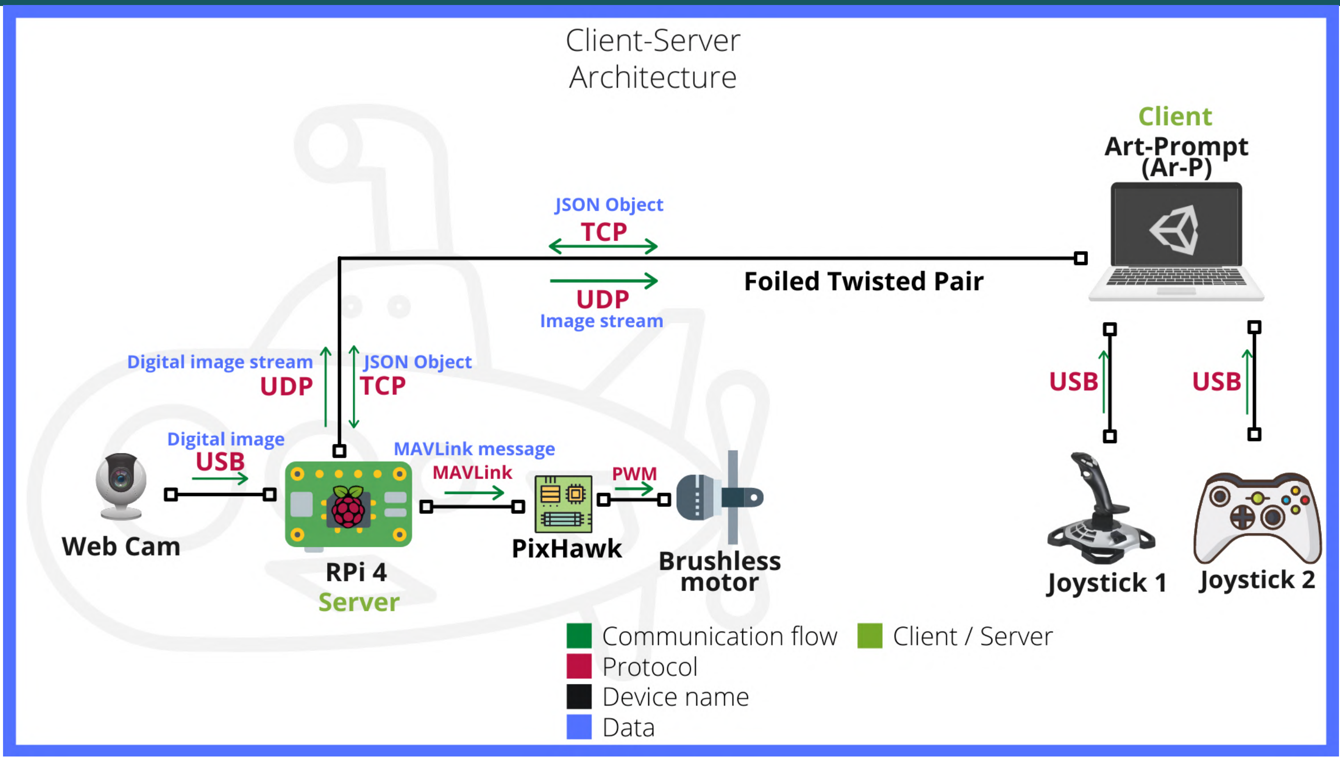


Fig. 21 Communication Flow Chart

B. STANDARDS FOLLOWED

The company uses GitHub and the version control manager of Unity during the project development.

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

8. MECHANICAL TOOLING

A. OVERVIEW

Kolop is equipped with certain tools that allow performing the tasks included in the RFP requirements. The implementation of tooling allows Kolop to perform the following activities: collecting pieces of plastic, debris, and nets from the ocean in order to reduce the pollution; coral reef harvesting; recognizing the healthy parts of a coral colony, and also relocating simulated coral pieces or sponges; maintaining the waterways healthy; removing traps to clean them, as well as being able to map out a structure.

B. TRIPLE GRIPPER

The need of manipulating objects with diverse and complex geometries has been one of the main challenges in previous designs. Our solution is that Kolop is now equipped with a soft triple gripper (Fig. 22). With this configuration; vertical and horizontal objects can be caught thanks to the symmetry and angle of separation of the gripper's fingers, making it perfect for catching a wide variety of objects and doing the task of cleaning plastic debris or collecting fragile objects like coral fragments easier.

The inspiration comes from soft robotics research and development. This type of equipment allows Kolop to reach a wider range of objects in comparison with a rigid claw. The soft consistency of the materials adapts easily to the surface of the objective and a double-action pneumatic piston provides enough pressure to avoid losing the object. The remaining body is made of 3D printed PLA; an organic filament easy to work with. The use of epoxy resin and silicone rubber was necessary to obtain the desired strength and durability. It is necessary to mention the use of safety measures to avoid accidents, such as the use of safety glasses and gloves. And silicone rubber is a non-biodegradable material that does not release toxic substances.

To ensure all the length of the pistons, a rod is used; the different parts of the claw had to be designed from scratch to achieve the maximum angle of aperture. The result is a five-piece mechanism. Three fingers, the support, and the union with the piston.

Fig. 22 Soft triple claw

C. SECONDARY GRIPPER

Kolop is equipped with a pneumatic parallel gripper (Fig. 23) reused from previous designs to perform tasks that require high force level for example task 1.1 Seabin (Reconnecting a new power connector to the recently installed Seabin).

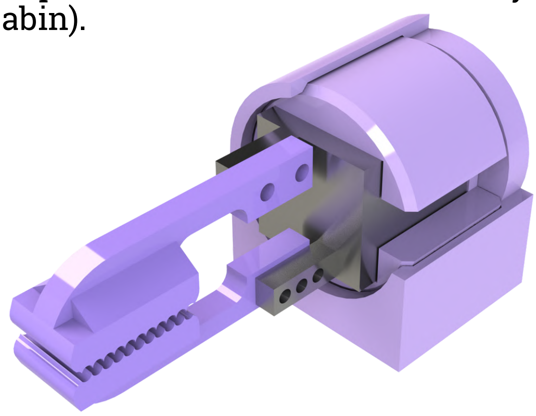


Fig. 23 Secondary parallel gripper

D. INTERCHANGEABLE GRIPPER SYSTEM

A balance between size restrictions and tools had to be struck. This problem is solved with an interchangeable gripper system. Using PLA and composite aluminum panels, the result is a 5-piece tool that allows the interchange of two grippers when needed, increasing the maneuverability, and keeping Kolop under the desired size dimensions (Fig. 24).

To power the tool a double-acting piston is used. When the piston expands it moves a claw outside of the frame, retracting the other one at the same time based on the lever principle. The same thing occurs when the piston contracts.

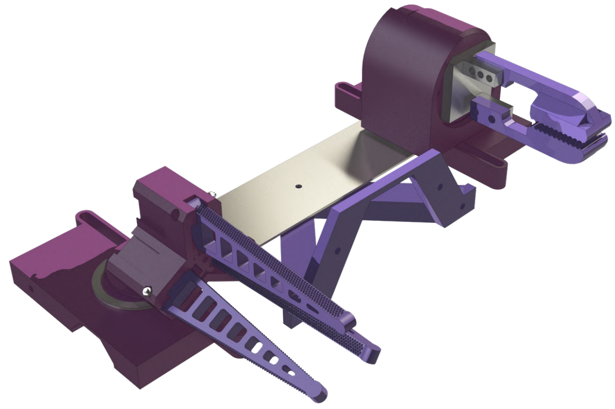


Fig. 24 Interchangable gripper system

E. PNEUMATICS

Since 2017 TecXotic has introduced pneumatic controls and actuators on its ROVs. These devices provide us with quick response, strength, and precision as well as being an alternative that does not harm the environment. The entire system is made up of two double-acting cylinders and a pneumatic gripper that are part of the Kolop's tools and controlled from the surface.

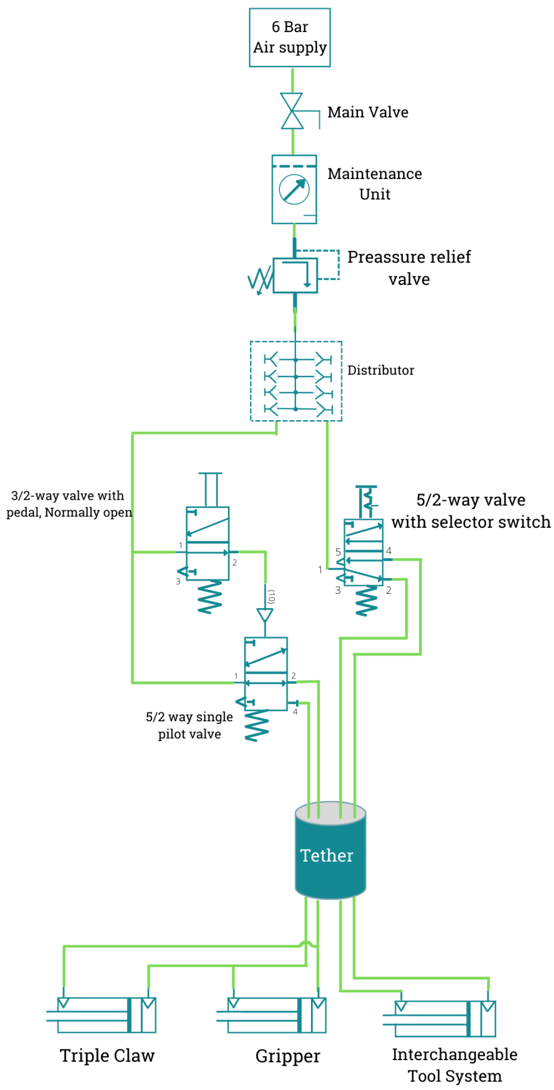
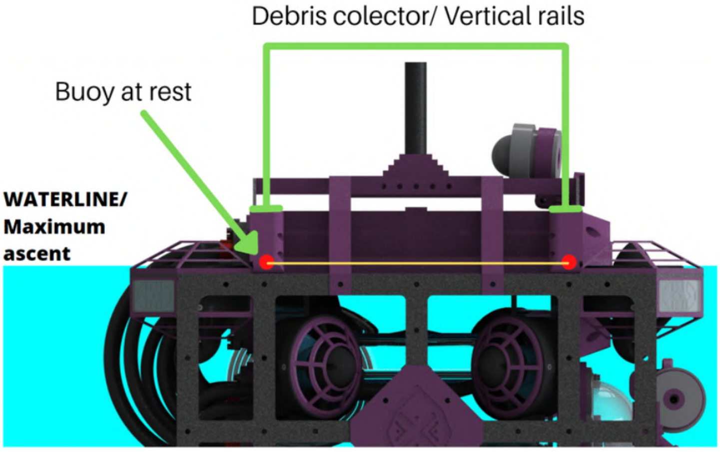


Fig. 25 Pneumatic system diagram



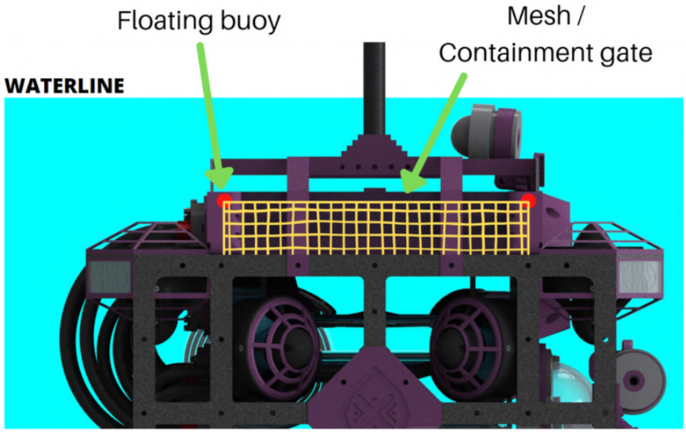


Fig. 26 Debris collector system

F. MAGNET

This is a perfect example of the philosophy SMW, planned for rapid task completion. It consists of a magnet that was strategically placed on the side of Kolop. It is highly effective in trapping magnetic elements, perfect for task 1.2 “Remediation: removing a ghost net from midwater” and other tasks that include metal parts.

G. DEBRIS COLLECTOR

To recover the floating plastic debris from the surface, a collection system has been implemented to take advantage of the physical conditions of the environment when carrying out this task (Fig. 26).

The system consists of two vertical rails located in the upper corners of the Kolop, inside each rail, there will be a buoy that will be tied to a mesh, this mesh will serve as a gate that allows us to contain the collected items.

To make this gate work, Kolop must be completely brought to the surface in order to introduce the plastic debris to the polluted structure. Once all the plastic debris has been introduced, the exposed part of the Kolop must be submerged again, causing the buoys to its’ interior begins to float, raising the mesh and ending by closing the gate, thus storing the plastic debris.

9. MICRO-ROV

R-Kolpito (Fig. 27) is a non-ROV device designed to collect a sediment sample while maneuvering through a 6-inch Corex drain pipe. The essential elements of this year’s model are 3 DC gear-motors, an endoscopic camera, 4 acrylic wheels together with a 3D printed cover, and a 3D printed frame. Its length is 24 cm, it is 13 cm wide, the diameter of the front wheels is 12 cm and the back ones are 6.6 cm in diameter.

The final result was an innovative design capable of sliding through the floor of the pool using both front wheels. The back wheels help R-Kolopito stabilize and they give it balance, all while providing extra torque to help boost its motion. R-Kolopito is equipped with a hook that helps retrieve the sediment sample.

The buoyancy is important, if R-Kolopito does not have the adequate weight it will float, this would not allow it to move through the pool floor. For this reason, the wheels were laser cut from an acrylic sheet, in an adequate weight. The Micro-ROV camera is located in the upper part of the structure, it has the correct position to be able to see clearly inside the tube.

The camera and motors are directly connected to the Kolop’s MCE, the motors are directly powered from Kolop and controlled via 2 H-bridges with a 12 V input. All electrical connections are included in the main SID

R-Kolopito will be deployed and powered from Kolop, a reel to extend and retract the cable will be used. The reel must wind a flat ethernet cable of 3.5 meters in length, avoiding the creation of any torsion on the edges of the cable. It is also as light as possible so it doesn't affect the balance of Kolop and R-Kolopito.

On the other hand, the reel consists of two laser-cut acrylic plates joined with a 3D printed center using epoxy resin. The plates have holes so the water can easily flow through them, reducing the resistance applied to the rotor.

Fig. 27 R-Kolopito and reel

Fig. 28 R-Kolopito

10. PROJECT MANAGEMENT

A. COMPANY ORGANIZATION AND ASSIGNMENTS

This year, the company had some major updates in the organizational structure to ensure an efficient operation. After five years, changes needed to be made, the standards of operation were updated, and new ones were created. TecXotic's corporate image was updated to match all these new ideas, being a company that cares is important to us.

The company has 5 main areas: safety, documentation and social media, design, programming, and electronics.

There are chief officers supervising specific elements in the project (Fig. 30), making sure that all targets are achieved and rules are being followed. This guarantees the safety of every member of the company and the optimal development during the current project.

The collaborators were divided into these five areas, forming specific task groups. Some of them participate in two different areas or teams, acting as the link between and allowing a homogeneous integration of each teams' work.

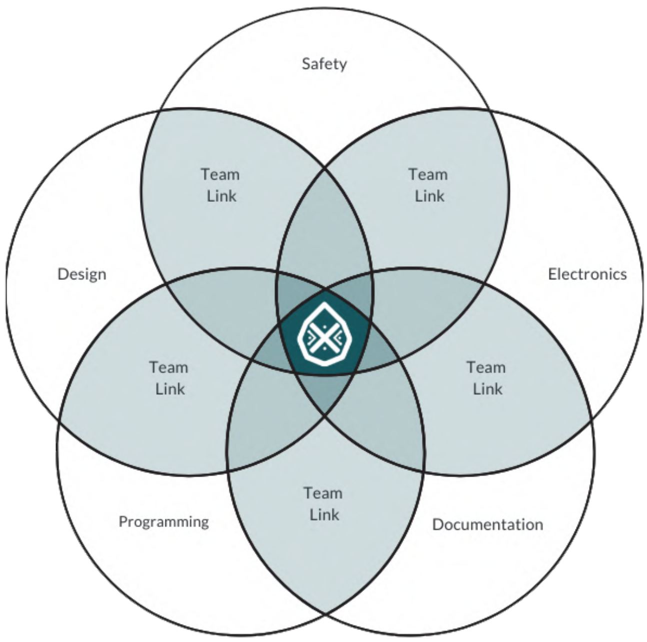


Fig. 29 Area integration diagram

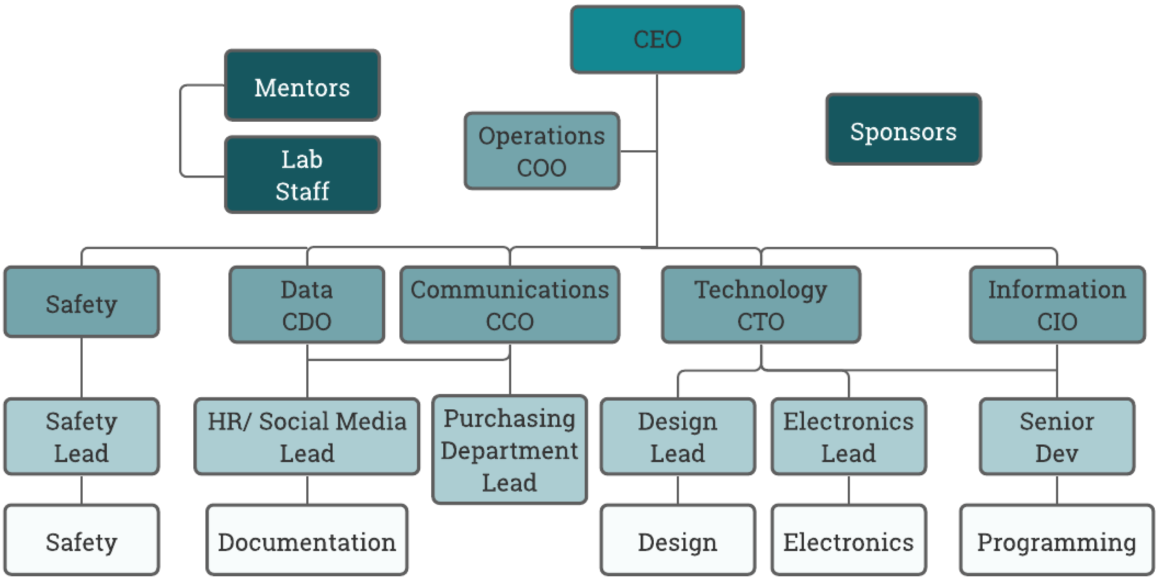


Fig. 30 Organizational diagram

B. PROJECT MANAGEMENT

Another improvement in the company's project management methodology is the adoption of the Agile ideology, this means that every team is constantly cycling through a process of planning, executing, and evaluating. This allows the segmentation of specific tasks in small self-managing cross-functional teams constantly iterating the design and improving with the ability to respond to unpredictability.

For a better mapping of the processes and a dynamic interaction between teams, this year the company is using the cloud-based platform "Click Up". Here, all team members can update their progress, create new tasks and let other teams see their progress for a future merging.

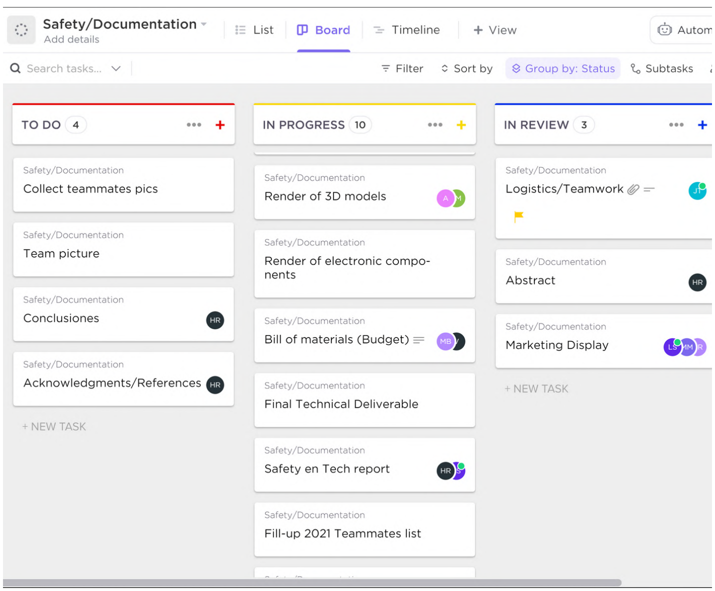


Fig. 31 Click UP tasks progress system

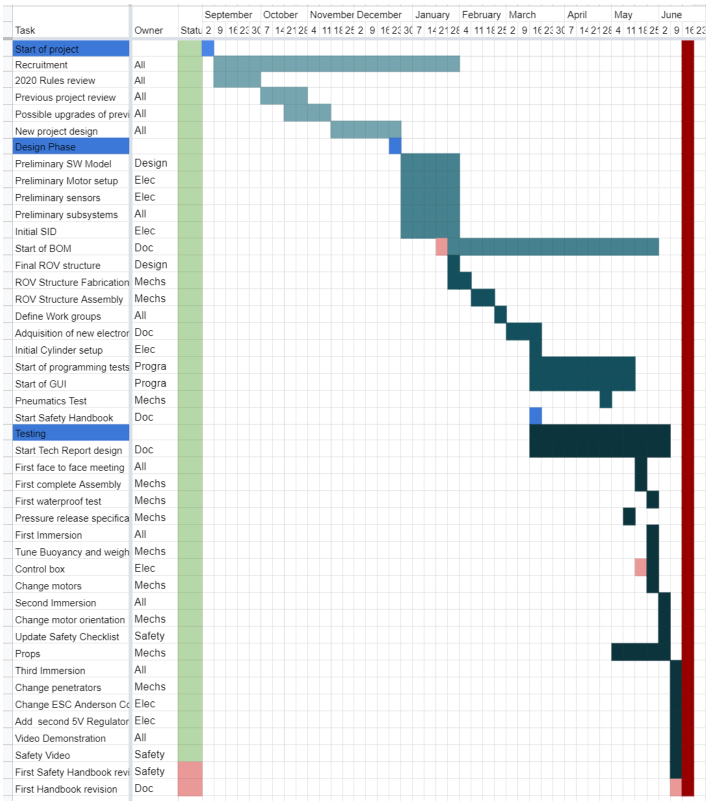


Fig. 32 Gantt diagram for project development

C. WORKFLOW

In order to have a proper development and a homogeneous integration, a weekly meeting was held with all areas. Moreover, each area hosts at least one meeting per week to update their progress, setbacks, and improvement of the tasks.

D. COLLABORATIVE WORKSPACE

Due to the health risk situation, face-to-face meetings were not always an option. Because the safety of the team members is a priority, all collaborative activities were held strictly following the guidelines stated in the company´s safety handbook (Working conditions during virus outbreak) and recommendations of government officials.

This led to the use of platforms such as Zoom, Discord, and Google Drive for efficient communication, and a proper organization of the planning, development, and documentation of the project. SolidWorks and Tinkercad were indispensable for the design, testing, and simulation phases. Github and Unity were widely used for software development.

E. BUDGET

The annual budget for project development was assigned based on the funding from Tecnológico de Monterrey Campus Cuernavaca. An individual budget was assigned to every department and was closely monitored to make sure all expenses were referred to the Purchasing Department.

As the company was working under a limited income, a significant number of components from previous designs were re-used to decrease Kolop´s production expenses. The main focus when purchasing new components was to introduce exceptional innovation and task-based tool development.

Employee transportation was not considered since these expenses are covered individually. A description of the project budget and project costing can be found in Fig. 33.

Electronic Expenses

Type	Part Name	Description	Cost (USD)
Re-used	Sensor & Controls/ Controller	Bar30 High-Resolution 300m Depth/Pressure Sensor // CUAV Pixhawk PX4 Flight Controller // Workstation Lenovo ThinkPad W541 Serie // Thrustmaster T. Flight HOTAS X // Flat TV	$ 1,239.65
Re-used	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
Purchased		Epoxy resin & catalyzer // Loctite Marine Epoxy // Enclosure Vent and Plug // Aluminum End Cap with 10 Holes (4" Series) // O-Ring Flange // Acrylic Tube // Epoxy resin (transparent) 1.5 kg	$ 333.38
Purchased	Voltage converter	Dc-dc Buck Converter Adjustable to 15a 200w 8-60v Input (3 pieces) // Control voltage regulator DC 6-40 V // DC-DC Converter	$ 277.78
Purchased	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
Purchased	FUSE	58V 40 A FUSE HOLDER // 30A 58V FUSE	$ 11.86
Purchased	Connectors and joins	Thermofit 1/8" - 1/2"// Bullet Polarised Connectors (100 pieces) // 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
Purchased	Illumination	Led Rgb Ws2812 (blue) // Neopixel Circular Cjmcu 12 Bit Ws2812 5050 Rgb Led	$ 23.10
Purchased	Micro ROV	Dual gear motor // Electric motor with gearbox // H-bridge	$ 39.57
Purchased	Electronical Components	Raspberry Pi 4 B-4GB // Powertec 71054 Switch // 7 Port Hub USB // Humidity control envelopes (100 pieces)	$ 159.90
Estimation Expenses:	$ 1,250.00	**Real Expenses:**	$ 1,244.11

Cameras System Expenses

Type	Part Name	Description	Cost (USD)
Re-used	Cameras system components	Aqua-Vu AV 715C // Foxeer Predator V3 Mini (2) // CCTV Recording System	$ 457.99
Purchased		Angular camera (2) // Servomotor // Silicone mold // Endoscopic camera	$ 64.34
Estimation Expenses:	$ 250.00	**Real Expenses:**	$ 64.34

Thruster Expenses

Type	Part Name	Description	Cost (USD)
Re-used	Thrusters	T100 Thruster & T200 Thruster	$ 1,252.00
Purchased	Basic ESC	A simple electronic speed controller for the T100 and T200 Thrusters.	$ 216.00
Estimation Expenses:	$ 300.00	**Real Expenses:**	$ 216.00

Pneumatics Expenses

Type	Part Name	Description	Cost (USD)
Re-used	Pneumatics components	Tubing // Valve with push botton // Valve with selector // Pneumatic distributor // Connnectors	$ 440.00
Purchased		Air compressor 25 L // Push Button Pneumatic Mechanical Valve // Pneumatic valve switch	$ 193.73
Estimation Expenses:	$ 200.00	**Real Expenses:**	$ 193.73

Manufacturing Expenses

Type	Part Name	Description	Cost (USD)
Donation	Frame	Composite aluminum panel	--
Re-used	Tools components	ROD-CYLINDER (2) // Gripper	$ 228.00
Purchased	Structure	2 x 1/8 in Squared Aluminium Bar // 1/8" x 1" bolts with nuts // 8 in. Cable Tie - Natural (100-Pack) // Hot Glue Sticks // 1/4 - 20 lock nuts 100 pieces box // 1/4 x 3/4 bolts // PVC 3/4" x 1 m pipe // PVC 1/2" x 1 m pipe // Dremel 3D Printer Filament (PLA) // Advanced Sanding Sheets (6-Pack) // M5*10 mm Hex nuts 50 pieces box // Bearing (5 pieces)	$ 1,033.09
Estimation Expenses:	$ 1,250.00	**Real Expenses:**	$ 1,033.09

Tasks & Proof Expenses

Type	Part Name	Description	Cost (USD)
Purchased	Product demostrations	1/2-inch PVC // 1/2-inch end cap // Paint // Paired wires // 1/2-inch tees // 1/2-inch 90 elbows // 18 gauge red black wire // Ping-pong balls // mesh // Colored duct tape // Industrial strength Velcro (white) // 6-inch Corex drain pipe // 5 gallon bucket // 1 gallon Ziploc bags // Pin / tent stake // LEDs // plastic test tube // Envirotex Lite	$ 344.18
Estimation Expenses:	$ 400.00	**Real Expenses:**	$ 344.18

Submarine, Equipment & Components Transportation Expenses

Type	Part Name	Description	Cost (USD)
Purchased	Flight	Flight tickets // Travel insurance // Submarine transport	$ 790.37
Purchased	Storage & Shelter	Submarine storage // PCR test (Responsible for submarine)	$ 274.01
Estimation Expenses:	$ 1,350.00	**Real Expenses:**	$ 1,064.38

Fig. 33 Total budget spreadsheet

11. TESTING AND THROUBLESHOOTING

This year a new approach for testing and validation was implemented, contemplating all areas like software, propulsion, buoyancy testing, and tools. It starts with the minimum component, evaluating if it works properly, then scaling up to a subassembly and repeat testing. Next, the assembly is tested and if it returns no error, the integration of all systems can be tested.

Troubleshooting works in a similar fashion, evaluating each step and understanding where the problem is located. Another method for validating physical designs is by simulating subsystems, with software such as Solidworks, ensuring it works properly. Next, a prototype is made with 3D printers and laser cutting in order to test before moving to the next iteration.

12. CONCLUSIONS

A. CHALLENGES

Working during the COVID-19 virus outbreak was one of the main challenges faced by the company this year. About 75% of the project was done remotely without face-to-face meetings. Adaptability was a key element as a company, all work had to be carefully planned and executed, following the authorities' guidelines. Also, the implementation of new technologies and manufacturing processes required more testing and training hours.

B. FUTURE IMPROVEMENTS

As a company advocates to develop high-impact technology, constant improvement is key. One of the future improvements in the implementation of different 3D printing materials like PETG instead of PLA, because of its higher resistance and lower absorption rate. Investing in training programs related to international safety standards and implementing VR on our systems is a must.

Next year a higher budget for the electronics department will be assigned in order to invest in a training program to develop our own electronics.

C. LESSONS LEARNED AND SKILLS GAINED

Never has TecXotic had so many new team members. Peer-to-peer interaction was essential to have proper interaction as a team. The working conditions required substantial compromise and effort from everyone to develop teamwork skills. One of the most important lessons during this edition that left us as a company is knowing that passion for what you do makes you invincible.

The whole world was closing its doors, and it seemed that the odds were not in our favor. Our passion for underwater robotics was the only certainty we had as a team, which let us develop the best ROV in the history of TecXotic. TecXotic reassured its commitment to develop high-impact technology that can bring a positive impact in the world. Because "Who cares, always wins".

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- Julio Noriega, Ph.D. - Dean of the School of Engineering and Science, South & Center Region, Tecnológico de Monterrey.
- Pascual Alcocer, MBA - Vice President of the South & Center Region, Tecnológico de Monterrey.

APPENDICES

Appendix I: Safety Check List

PRE-POWER UP

- Clear area (no tripping hazards or items in the way).
- Power switches are off.
- Tether flaked out on the deck.
- Tether connected to control station and secured to ROV.
- Tether connected to control station and secured in a solid area.
- Tether properly attached to the ROV with the tensor relief.
- Verify that the electronics enclosures are appropriately sealed.
- Perform a vacuum pump test in the electronics enclosures maintaining a pressure of -10 to -15 bar for 5 minutes.
- Perform a visual inspection of electronics enclosures for damaged wires and/or lose connections.
- All nuts are tight on the electronics enclosures.
- Thrusters are free from obstructions.
- Power source connected.
- The vacuum port is securely capped.

POWER UP

- The power supplying 48 volts nominal.
- Computers are up and running.
- Ensure deck crew members are attentive and in their positions.
- Call out “Power On”.
- Wait for thrusters and ESCs to be armed. Call our “Armed”.
- Perform thruster test.
- Perform pneumatics test.

LEAK DETECTION PROTOCOL

- If there is a visible leak or unusual bubbles, any member may call out “Leak”.
- Verify that the electronics enclosures is appropriately sealed. Perform a vacuum pump test in the electronics enclosures maintaining a pressure of -10 to -15 bar for 5 minutes.
- Push emergency stop button.
- Surface immediately.
- Inspect (may require removal of electronics).

IN-WATER

- Check for unusual bubbles.
- Visually inspect for water leaks.
- If there are any large bubbles, immediately push the emergency stop button and then pull the ROV to the surface.
- Make sure the tether manager is standing at least 1.5m from the edge of the pool.
- Begin operations.
- The pilot and copilot must call out the tasks as they perform them.

ROV Retrieval

- The pilot calls “ROV up” and deactivates thrusters.
- Deck crew calls “ROV captured”.
- Operation Technician (OT) powers down the power supply.
- After securing the ROV on deck, deck crew calls out “ROV out”.

LOSS OF COMMUNICATION

- Call out “Communication lost”.
- Retrieve ROV via the tether.
- Take ROV completely out of water
- Reboot PuTTY and QGroundControl.
- Call out when the connection is reestablished.
- Arm ESCs.

LAUNCH

- Call out “Prepare to launch”.
- Deck crew members handling ROV call out “Hands-on” as they approach the edge of the pool.
- Launch ROV, maintain handhold.
- Wait for pilot to say “Launch”.

PIT MAINTENANCE

- Verify thrusters are free of debris and spin freely.
- Visual inspection for any damage.
- All cables are neatly secured.
- Visual inspection for leaks.
- Verify camera positions.
- Perform pneumatics test.

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