ACOATL

2019
TECHNICAL REPORT

TECXOTIC

Tecnológico de Monterrey

Cuernavaca, Morelos, México.

Paola Yunes Sordo Company - Executive Officer - 6th Semester
Luis Diego Hernández López - Company Operative Officer - 6th semester
Luis Enrique Carvajal Pallares - Chief Technology Officer - 10th semester
Ana Paola Serrano Guadarrama - Safety Captain - 6th semester
Luis Miguel Gómez Lomelí - Electronics Leader - 8th semester
Raúl Orihuela Rosas - Software Leader - 6th semester
Jael Abraham López García - Design Leader - 6th semester
Luis Antonio Ortíz Sandoval - Mechanics - 2nd semester
Jesús Alberto Zaragoza Pineda - Mechanics - 4th semester
Luis Raúl del Moral Contreras - Mechanics - 4th semester
José Julio Fragoso Figueroa - Mechanics - 2nd semester
Hilda Teresa Rojas Alemán - Mechanics - 2nd semester
Raúl Cruz Castrejón - Mechanics - 2nd semester
Othón Ramírez de Ávila - Electronics - 8th semester
Santiago Gonzáles Quevedo - Electronics - 8th semester
José Antonio Aguilar Tellez - Electronics - 8th semester
Alejandro Visoso Valentín - Electronics - 4th semester
Eduardo Ahumada García Jurado - MicroRov - 6th semester
Javier López Miranda - MicroRov - 6th semester
Raquel Hernández Quinto - Communication - 8th semester
Helena Stefania Serrano Sánchez - Communication - 8th semester
David Garcia Suarez - Mentor

Table of Contents

Abstract

Acoatl is a Remotely Operated Vehicle (ROV), designed to do maintenance work inside hydroelectric dams, as well as to carry out conservation work on rivers and lakes, without affecting the ecosystem. It has been specifically designed to perform inside the BOONE dam, rivers and lakes, while meeting the requirements presented by MATE.

TecXotic is a company made up of 25 people who have the necessary skills, both in engineering and business, to develop an ROV that meets the specifications proposed by the client. TecXotic has a highly qualified team for the different areas involved in the development of an ROV. These are divided into 4: Design and Manufacturing, Electronic and Control Systems, Software Engineering and Marketing and Logistics.

Within TecXotic, security must meet the highest standards, therefore, Acoatl was created under strict security protocols in order to deliver the target customer an ROV that contains the required specifications. Following the described path has led us to the development of the most advanced ROV ever created by the company.

Figure 1 - TecXotic Team Members

Design Rationale

Evolution of the design

Acoatl is the result of several years of experience in the development of ROVs, improving all possible aspects. On this occasion, and due to the needs of this year's tasks, a design was implemented with 8 thrusters as opposed to 6 last year, in order to increase its power when lifting heavy objects. The same engine configuration was used to give stable movement allowing the 6 degrees of freedom required. The structure was manufactures with a material called reynobond, an ultra-light plate composed of two exterior aluminum plates and a layer of polyethylene in the center. This reduces the weight without losing resistance. The ROV has a diameter of 63 cm, as it has a configuration of 8 thrusters and several tools.

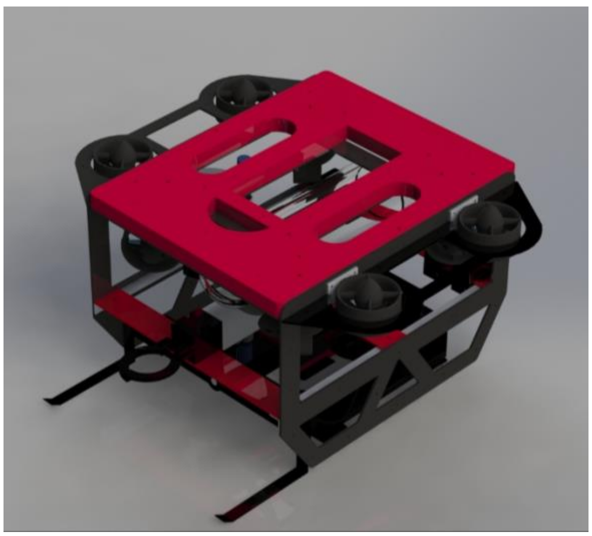


Figure 3 - Acoatl CAD

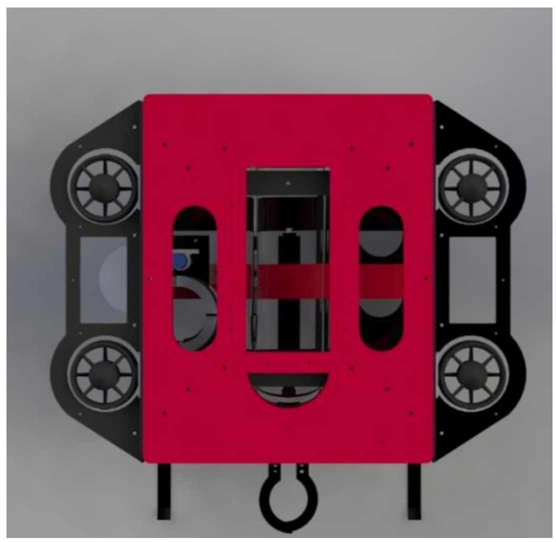


Figure 2 - Acoatl Top View

The diameter of Acoatl include in its interior the necessary tools to fulfill the missions, as well as to store the Micro-ROV.

The main change in the design of this year was its ability to withstand greater loads, taking into account the missions that were proposed. It was also necessary to consider the water flow of the thrusters, so as to gain strength without losing mobility.

Tools

Fish transportation tool

For the second task it was necessary to develop a device capable of storing, transporting and releasing trout. A compact design was achieved so that it could be placed on the back of the ROV. Lightweight materials avoid decompensation of the weight of the ROV. All the pieces manufactured on acrylic were laser cut, and those made of 3D printed PLA were treated with epoxy.

Figure 4 – Fish transportation tool

The structure of this tool is made with 9mm acrylic. The top structure encases the fish and is covered with a thin mess that allows water flow while preventing the fish from escaping. The bottom of the tool is made of a rotating acrylic piece. Powered by a DC motor, when actioned it frees the fish in the desired location. The opening is wide enough to ensure that all fish will be released.

Gripper

Acoatl is equipped with a pneumatic gripper that can perform different tasks, thus our main tool. The gripper is designed to perform tasks that require high force level, an improvement we made from past years. This gripper is mounted on the front of the ROV, in order to have a good viewing angle to perform the tasks needed. This gripper is fastened with screws to a main tool bar manufactured with reynobond.

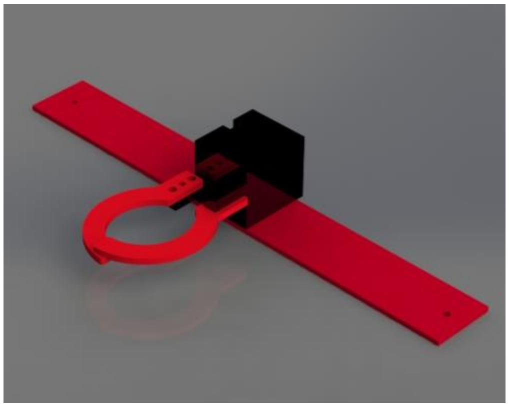


Figure 5 - Gripper CAD

Buoyancy and stability

The mechanical design department took on the task of designing the buoyancy system, as in previous years. A floating device of polyurethane foam shaped as the top structure was made. Movement in the vertical axis was significantly improved. Uniform buoyancy was proudly achieved, something that had proved to be challenging in the past years. A wooden mold was necessary in order to achieve the best outcome.

Figure 6 - Buoyancy System

Pneumatics

The multifunctional gripper, double acting cylinder and liftbag noozle are activated with pneumatics. A pneumatic system operating at 3 psi is used. The gripper is controlled by a 5/2-way valve, with selection switch. A tube acts as the liftbag nozzle, which injects air to it and allows it to inflate. The air flow is regulated with a normally open push button. This provides floatability to the ROV when it carries more weight in the front.

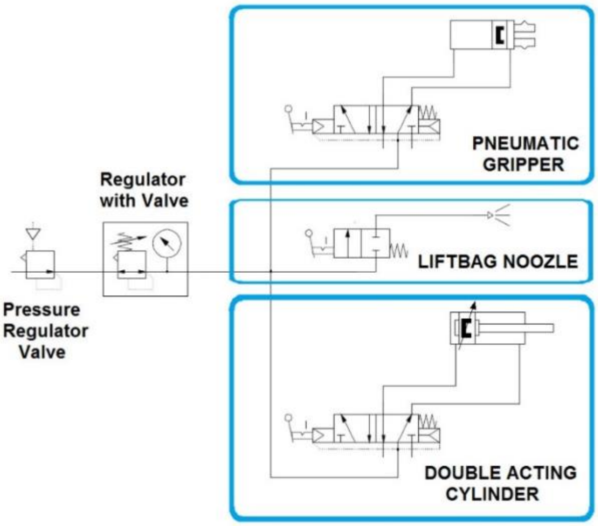


Figure 7 - Pneumatics SID

The double acting cylinder is the third de vice. The piston is manipulated with another 5/2-way valve, with selection switch. This cylinder moves an auxiliary structure that helps the ROV hold on to large and heavy objects. The three mechanical controllers are located inside a tailor-made control box. This box is placed at hand-range of the second pilot.

Micro-ROV

This Micro-ROV design consists of 14 components:

- Mirco-ROV frame
- 5 Core-less Motors
- 5 propellers
- Underwater Endoscope camera
- Nano Arduino
- Printed circuit board

The Micro-ROV is formed by 5 Coreless Motors, 4 at the top as shown in Figure I. This enables the pitch and roll movement. Also, there is a Coreless Motor at the back of the frame to move forward.

An endoscope camera is placed at the front of the Micro-ROV. This camera has 6 LED´s and works with a power supply provided from outside the pool. Figure II shows the front view with Endoscope Camera.

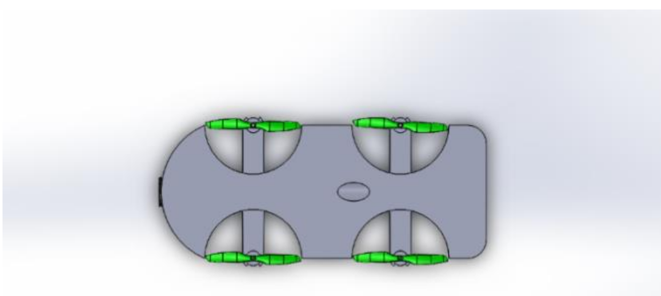


Figure I – Top view of the Micro-ROV

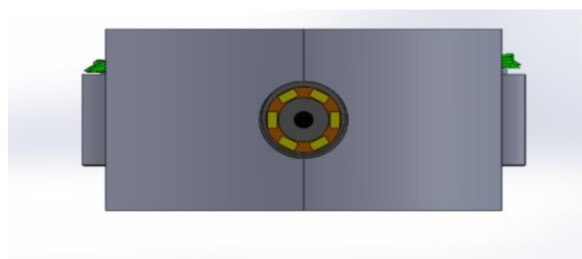


Figure II – Front view of the Micro-ROV

Manufacturing Process

The manufacturing process of Acoatl was a very important task, since it is key for a correct assembly of all parts. The main machinery responsible for the manufacture of Acoatl is the CNC router. The main frame, made out of reynobond, was cut with precision. Using the router allowed us to manipulate the material without damaging it and minimizing errors. Therefor, there was no waste generated from a mistake in manufacture.

Figure 8 - Manufacturing process

Thanks to this technology, we achieved one of the objectives we had for the past years, to manufacture an ROV that could support large loads. Fastening with screws was preferred over welding, since the material is mainly aluminum. This decision is also strongly preferred taking into account the transportation of Acoatl to the desired site.

The design is made in such a way that it can be easily stored in a small suitcase. Most important, the assembly process is fairly simple and minimally time consuming.

Figure 9 - First functional prototype

Laser cutting was a fundamental method for the manufacturing process, since several prototypes were made before achieving the final design.

Many designs were tested, searching for the one that provided greater stability. All these prototypes were manufactured in 9mm wood, which was subsequently treated with epoxy.

Another essential manufacturing process was 3D printing, due to its versatility and low cost. This allowed us to experiment with different designs for tools and cases a great number of times. By creating tailor-made cases for the DC motors used and the thrusters we ensure optimal conditions of these components.

Electrical System

Power supply system

The power system of Acoatl allows us a good management of the power delivered by MATE. Since all the components in our system operate at 12VDC, a DC-DC Converter 48-12VDC was implemented at 30A. In previous years this converter worked properly and therefore it was considered for this year's design.
The output of the DC-DC converter is connected to the DC-DC converter, LM2596, that converts to 5V.

Figure 10 - Murata DC-DC converter

Control System

The stability of Acoatl is an improved aspect this year. Hence, a Pixhawk 4 was used. Its integrated IMU (Inertial Measurement Unit) plays a fundamental role on the stability of the control system. This allows a better integration at the electronic level and a more efficient use of processing resources.

The Pixhawk has communication interfaces, which allow us to implement sensors more easily. However, because this controller does not have robust communication interfaces, it is joined by a Raspberry 3B + that supplies more computing capacity. This allows us to meet MATE requirements easily.

Figure 11 - Main computer of Acoatl

Propulsion system

For the fourth consecutive year, BlueRobotics Thrusters have met our performance requirements. We are using 4 T100 Thrusters, which can generate a force of up to 2.6Kgf each, for the movements in Horizontal axis. These were placed at 45 °, which will allow us to have a resulting vector that applies the power of the 4 motors.
To achieve control in the vertical direction 4 Thruster T200 are used, since these provide us with up to 3 kgf each. This will allow us to carry out the missions established by MATE. Both thrusters have an operating voltage of 12V.

Figure 12 - Thruster T200 blue Robotics

Tool's Electronic

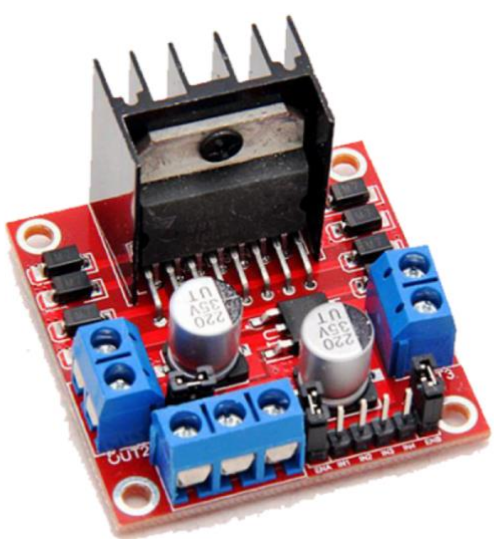


Figure 13 - L298 Motor Driver

To achieve the control of the fish tool it was necessary to implement a DC motor controller. An L298 was used because it allows us to handle higher currents. The DC motor is perfectly sealed and waterproofed, and it has a protecting case.
The rotation of the axis is activated by PWM through the Pixhawk, which allows us to have better control of the actuator.

Vision System

The Acoatl vision system is one of the fundamental parts as it is the link between the environment and the pilot. It was decided to implement 3 cameras. Two of them are inside the electronic box. These are Foxeer Arrow Mini Pro 2.5mm and send the signal to the surface through the Theater. The third camera is a fisherman's camera, placed specifically to oversee the fish tool's performance.

Figure 14 - Foxeer Camera

Power Budget

MATE will provide us 1600W of power for use within Acoatl, however, after doing the power analysis needed, it was concluded that only 735W was needed.

Device	Quantity	Max. Power(W)	Nominal Voltage(V)
T100 Thruster	4	77	12
T200 Thruster	4	98.6	12
Raspberry pi 3b+	1	2	5
Pixhawk 4	1	2	5
Arduino Nano	1	0.23	12
DC-DC Converter	1	25	48
Mini DC motors	4	0.6	5
Ph sensor	1	0.05	5
Metal Sensor	1	0.65	5
DHT11	1	0.07	5
Camera	3	0.54	12
Dc Motor	1	0.3	12
Total Consumption		734.92	

The calculated power consumption is 735W, calculating the fuse, it was concluded that a 30A fuse is necessary.
Fuse = Total consumption*(150%) = 734.9248*1.5 =22.96A

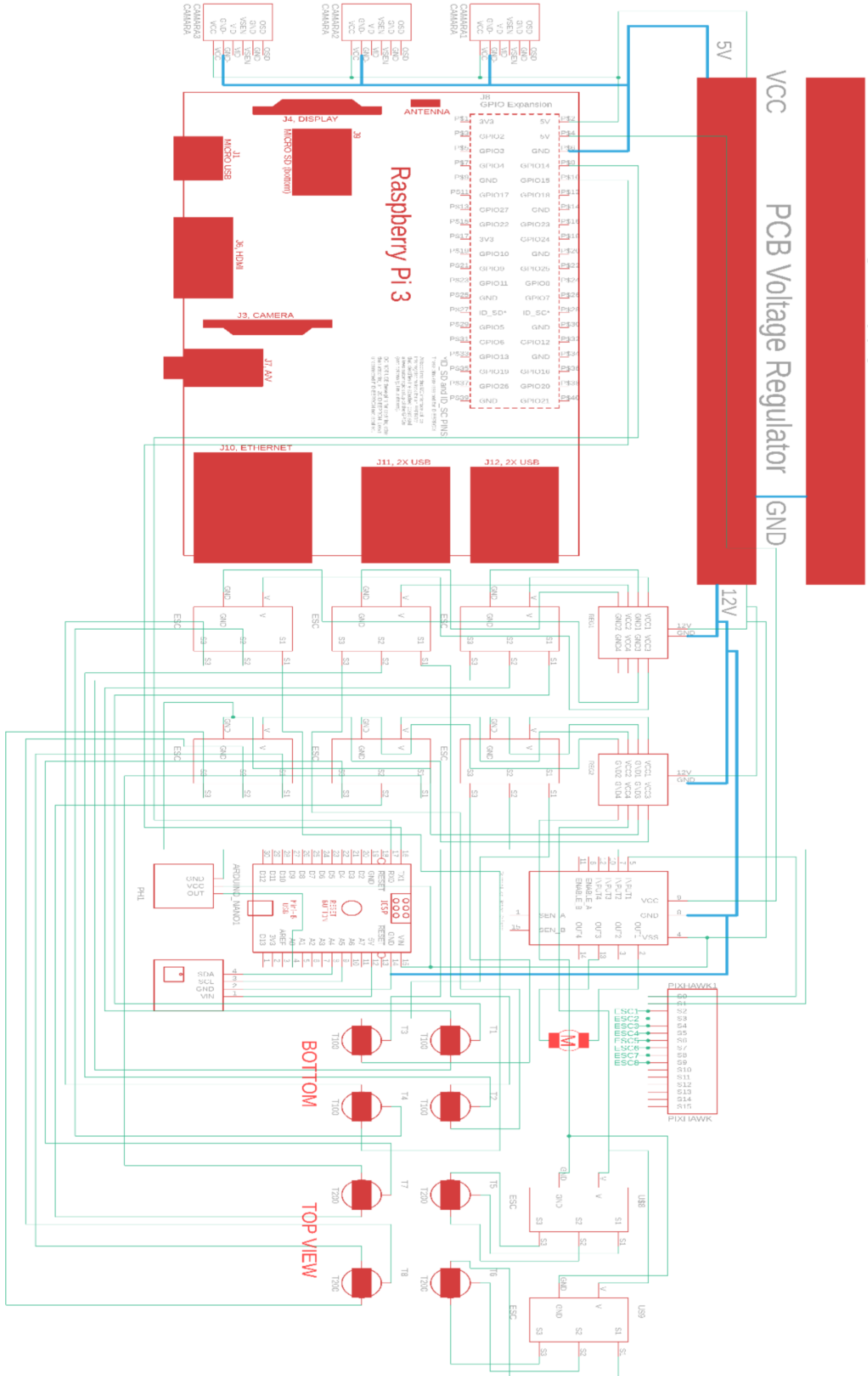


Figure 15 - Electronics SID

Software

System Overview

TecXotic's ROV Software is built in an environment as described in the following diagram.

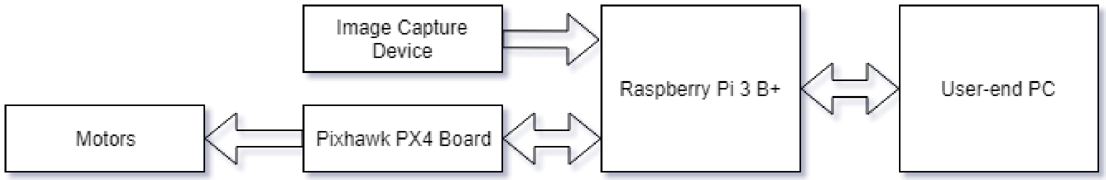


Figure 16 - Software Diagram

The user communicates with the ROV through the User-end PC. This PC communicates via Ethernet with the Raspberry Pi 3 B+, which is an on-board computer. This computer is used to process image and user inputs before sending an output to the Pixhawk board. The Pixhawk PX4 Board is used to gather telemetry data (GPS, orientation, speed, etc.), as well as sending voltage output to the motors

The software used by TecXotic is composed of interconnected components in order to accomplish all of its functionalities. The first functionality is allowing the pilot to manually operate the vehicle. The second functionality is to use image recognition in order to process camera inputs. The third functionality is to use the image recognition data to pilot the vehicle.

The components and external systems' interactions are described in the following diagram:

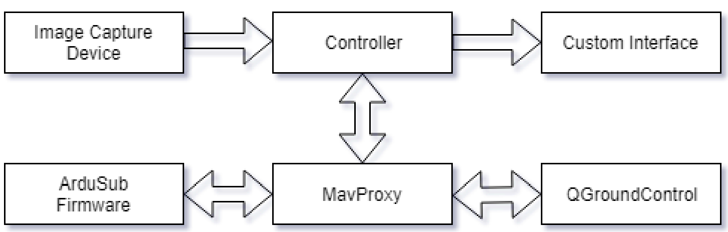


Figure 17 - Interactions Systems

ArduSub Firmware

Resides in the Pixhawk PX4 Board. This system receives input data from the Pixhawk sensors and sends them as a MavLink Protocol Messages. This system also receives input in the form of MavLink Protocol Messages and gives output to the motors.

MavProxy:

This system is contained in the Raspberry Pi computer. It is used to link the Pixhawk PX4 Board and the User-end computer, while providing an interface for other modules running in the Raspberry Pi.

QGroundControl:

QGroundControl resides in the User-end PC. It is used to process the user input and then send it as MavLink Protocol Messages onto MavProxy. It is also used to display to the user telemetry information gathered from the pixhawk sensors.

Image Capture Device:

The image capture is done by a camera. This is used as input data for the Controller in order to process the image.

Controller:

This module is contained in the Raspberry Pi. This module is used to process the data captured by the Image Capture Device via computer vision. This is done with OpenCV, a computer vision library for Python. The processed information is added as an overlay to the current image frame. The resulting images are sent as an output to be displayed on the Custom Interface.

This module is also used to send MavLink Protocol Messages to MavProxy when the ROV is used in automatic mode to follow a path along a straight line.

Custom Interface:

This module is used to display images from the Image Capture Device to the user, after being processed by the Controller.

Computer Vision Algorithms

Line Following Algorithm

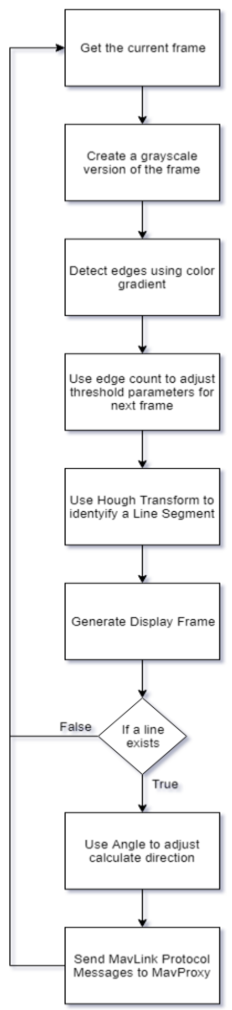


Figure 18 - Flow chart of line following

The Line Following algorithm is run on a constant loop. The first step of the algorithm is to get the current frame of video. Then a grayscale version of the frame is created, this is done in order to simplify calculations of the color gradient. The next step is using Canny Edge Detection on the grayscale image. The output of this process is a binary colored image, with white and black pixels.

This image represents the edges by using this image the algorithm can know whether too many edges are being detected, as a sign of noise or if too few edges are being detected. This allows the algorithm to, respectively, raise or lower the threshold of the edge detection.

Then, the Hough Line Transformation is applied to detect straight lines in the image. Then, the line is added to the frame as an overlay to create the display frame for the user interface.

If a line is detected, the orientation is used in order to determine the direction the ROV should follow. Then, through MavLink Protocol Messages, commands are given to the MavProxy System in the Raspberry Pi in order to move the ROV's motors.

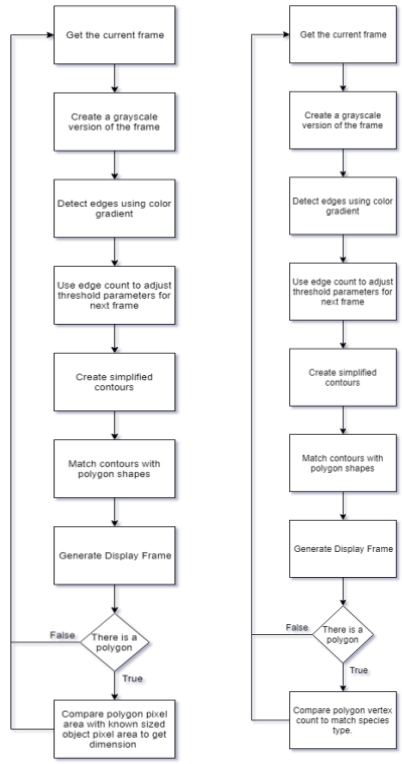
Crack Recognition Algorithm / Benthic Species Algorithm

The Crack Recognition Algorithm and Benthic Species Algorithm are very similar to the previously described Line Following Algorithm. Both algorithms start by taking the current frame of the video and creating a grayscale version of the frame. Then, the same process of getting the edges through a color gradient is applied and using the edge count to adjust the threshold parameters for the next frame.

The differences come after this step. Instead of using Hough Line Transform, we use an OpenCV function to get a polygonal approximation of the edges.

For the Crack Recognition Algorithm If a polygonal shape is found, then the pixel area that the object occupies is compared against a known-sized object. This gives us a way to linearly approximate the size of the given polygon. The known-sized object used for this comparison can be a part of the ROV that appears in the field of view of the camera.

For the Benthic Species Recognition Algorithm, the polygon's vertex count is used to match the representation with the given species.



Grid Map Algorithm

The Grid Map Algorithm is used for mapping the events that have occurred along the mission. First, the starting position of the ROV is retrieved from MavProxy. This is used to center the Grid Map.

After a new event is registered, the position is retrieved from MavProxy as a GPS point. This position is compared with the list of event occurrences to avoid duplicating an event.

If this is detected as a new event, the new position is added to the event list. Then the maximum difference of distance from the center to an event occurrence is calculated. This maximum distance is then used to scale the distance in which the events will be displayed in the grid map. After this, the map is updated.

SAFETY

Company Safety Philosophy

Safety is a core value for TecXotic. Employees are taught all safety guidelines provided by MATE, focusing not only on the prevention of accidents, but also in improving the operating processes. An employee's safety is our highest priority, so we provide training programs, excellent work environment and safety protocols which must be followed at all times.

Protocols

To ensure a safe work environment, safety protocols were design according to MATE safety standards. Prior to the ROV construction, TecXotic provides Job Safety Analysis (JSA) forms to the employees in order to arise awareness when a risky task will be performed. JSA manuals were also given to laboratory managers in order to maintain a safe work environment.

Safety Checklists (located in Appendix A) and JSA forms were followed closely before, during and after ROV operation, such as launch, recovery and deck security.

Safety Features

Acoatl has numerous safety features that keep employees, work environment and the non-ROV devices safe during operation. A master fuse is placed on the tether between the ROV and the power supply. Several waterproof techniques were used in the electronics enclosure to prevent them from water exposure. A leak detector monitors humidity inside the electronics enclosure to prevent short circuits. If a leak occurs, the Raspberry Pi has a shutdown protocol notifying the pilot. This is followed by pulling out the ROV manually to the surface by the deck crew. A tensor release device is placed on top of the ROV and the Operations Table, ensuring safety on Acoatl electrical connectors. Transparent electronics enclosure provides a clear view on electronic components.

Logistics

Budget and Project Costing

Production Expenses	Part ID	Part name	Description	Supplier	Qty	Units	Unit Cost	Cost	Type
Cameras	CA-001	Aqua-Vu AV 715C	Aqua-Vu AV 715C Underwater Viewing System with Color Video Camera and 7" LCD Monitor	Cabela's	1	piece	$ 299.99	$ 299.99	Re-Used
Cameras	CA-002	Logitech C920 Web Cam	Logitech C920 USB Web Cam	Office Depot	1	piece	$ 81.00	$ 81.00	Purchased
Cameras	CA-003	Cameras	Foxeer Predator V3 Mini FPV HS1217 1000TVL Super	LUCAP	3	piece	$ 48.00	$ 144.00	Purchased
Cameras	CA-004	CCTV Recording System	CCTV Recording System	LUCAP	1	piece	$ 62.00	$ 62.00	Purchased
Controls	CO-001	Thrustmaster T. Flight HOTAS X	The T. Flight HOTAS X from Thrustmaster is a programmable joystick and throttle that is compatible with PCs and PS3 systems for realistic flight simulation.	Fry's Electronics	1	piece	$ 49.99	$ 49.99	Re-Used
Controls	CO-002	Workstation Lenovo ThinkPad W541 Serie	Intel Core 4, Invidia Optimus, Thunderbolt port	Lenovo	1	Computer	$ 862.00	$ 862.00	Purchased
Controls	CO-003	Flat TV	19" Flat LED TV	Best Buy	1	piece	$ 55.00	$ 55.00	Re-Used
Electronics	EL-001	Bar30 High-Resolution 300m Depth/Pressure Sensor	This pressure sensor can measure up to 30 Bar (300m depth) with a depth resolution of 2mm. It is waterproof and ready to install.	Blue Robotics	1	piece	$ 68.00	$ 68.00	Purchased
Electronics	EL-002	Electronic Speed Control ESC 20A	afro ESC 20Amp del Electronic Speed Controller (SimonK firmware)	Hobby King	8	piece	$ 11.25	$ 11.25	Re-Used
Electronics	EL-003	Turnigy Pure-Silicone Wire 14AWG 1m (Blue)	Turnigy Pure-Silicone Wire 14AWG 1m (Blue)	Hobby King	4	meter	$ 4.00	$ 16.00	Purchased
Electronics	EL-004	Turnigy Pure-Silicone Wire 14AWG 1m (Red)	Turnigy Pure-Silicone Wire 14AWG 1m (Red)	Hobby King	4	meter	$ 4.00	$ 16.00	Purchased
Electronics	EL-005	DC/DC Converter	Digikey Isolated DC/DC Converter 500W 38-75Vin 12Vout N Log	Digikey	1	piece	$ 157.00	$ 157.00	Re-Used
Electronics	EL-006	RASPBERRY PI 2 MODEL B	The Raspberry Pi 2 Model B is the second-generation Raspberry Pi.	Raspberry	1	piece	$ 53.00	$ 53.00	Re-Used
Electronics	EL-007	Triple-axis Accelerometer+Magnetometer	Triple-axis Accelerometer+Magnetometer (Compass) Board - LSM303	Adafruit	2	pieces	$ 14.95	$ 29.90	Purchased
Electronics	EL-008	3.3V 800mA Linear Voltage Regulator	3.3V 800mA Linear Voltage Regulator - LD1117-3.3 TO-220	Adafruit	1	pieces	$ 1.25	$ 1.25	Re-Used
Electronics	EL-009	58V 40 A FUSE HOLDER	FUSE HLDR BLADE 58V 40A IN LINE	Digikey	1	pieces	$ 9.92	$ 9.92	Re-Used
Electronics	EL-014	Controller	CUAV Pixhawk PX4 Flight Controller	LUCAP	1	piece	$ 204.75	$ 204.75	Purchased
Pneumatics	PN-001	Tubing	FESTO Pneumatic tubing 6 x 1 m	FESTO	60	meter	$ 1.70	$ 102.00	Purchased
Pneumatics	PN-002	Valve with push botton	FESTO 3/2 pmneumatic valve with push button	FESTO	2	piece	$ 80.00	$ 160.00	Re-Used
Pneumatics	PN-003	Valve with selector	FESTO 4/2 pmneumatic valve with selector	FESTO	1	piece	$ 102.00	$ 102.00	Re-Used
Pneumatics	PN-004	Pneumatic distributor	FESTO 6 way pneumatic distributor	FESTO	1	piece	$ 38.00	$ 38.00	Re-Used
Pneumatics	PN-005	Mainteinance Unit	FESTO Mainteinance Unit and Regulator	FESTO	2	piece	$ 78.00	$ 38.00	Re-Used
Pneumatics	PN-006	Connnectors	FESTO 6 mm fast connector	FESTO	14	piece	$ 78.00	$ 38.00	Re-Used
Structure	ST-001	Acrylic Sheet	400 x 800 x 9 mm uncolored acrylic sheet	Grupo Grabado	1	sheet	$ 480.00	$ 480.00	Donated
Structure	ST-002	2 x 1/8 in Squared Aluminium Bar	2 x 1/8 in Squared Aluminium Bar	Aceros vijaf	2	Bar	$ 15.00	$ 30.00	Purchased
Structure	ST-003	1/8" x 1" bolts with nuts	1/8" x 1" bolts with nuts	Home Depot	20	pieces	$ 0.25	$ 12.50	Purchased
Structure	ST-004	8 in. Cable Tie - Natural (100-Pack)	8 in. Cable Tie - Natural (100-Pack)	Home Depot	2	pieces	$ 7.21	$ 14.42	Purchased
Structure	ST-005	Hot Glue Sticks	10 in. x 7/16 in. Dia Hot Melt Multi Temperature Full Size Glue Sticks (5 lb. Bulk Pack)	Home Depot	1	box	$ 21.41	$ 21.41	Purchased
Structure	ST-006	Alucobond Sheet	Alucobond Composite Panel 1.22 x 2.44 m	Alucobond	1	piece	$ 90.00	$ 90.00	Donated
Structure	ST-007	Nuts	1/4 - 20 lock nuts 100 pieces box	Home Depot	1	box	$ 7.95	$ 7.95	Purchased
Structure	ST-008	Bolts	1/4 x 3/4 bolts	Home Depot	1	box	$ 10.00	$ 10.00	Purchased
Structure	ST-009	Float	PVC 3/4" x 1 m pipe	Sodimac	4	piece	$ 1.02	$ 4.08	Purchased
Structure	ST-010	Float	PVC 1/2" x 1 m pipe	Sodimac	2	piece	$ 0.89	$ 1.78	Purchased
Structure	ST-011	Float	PVC 90 Connector	Sodimac	4	piece	$ 0.10	$ 0.40	Purchased
Structure	ST-012	Float	PVC T join	Sodimac	4	piece	$ 0.20	$ 0.80	Purchased
Structure	ST-013	Paint	Rust Oleum Truck Bed Coating Spray	Home Depot	2	piece	$ 12.30	$ 24.60	Purchased
Structure	ST-014	Paint	Rust Oleum Metal Protection Red	Home Depot	2	piece	$ 7.70	$ 15.40	Purchased
Structure	ST-015	Paint	Meridian Flourescent Orange Spray paint	Home Depot	1	piece	$ 1.80	$ 1.80	Purchased
Tether	TE-001	THWN WIRE (2 x 12 AWG)	THWN WIRE (2 x 12 AWG RUBBER COVER)	Home Depot	18	meter	$ 1.50	$ 27.00	Purchased
Tether	TE-002	UTP CAT6 WIRE	UTP CAT6 ETHERNET WIRE	Steren	18	meter	$ 0.25	$ 4.50	Purchased
			HATCHBOX 3D PLA-1KG1.75-WHT PLA 3D Printer Filament, Dimensional Accuracy +/- 0.05 mm, 1 kg						

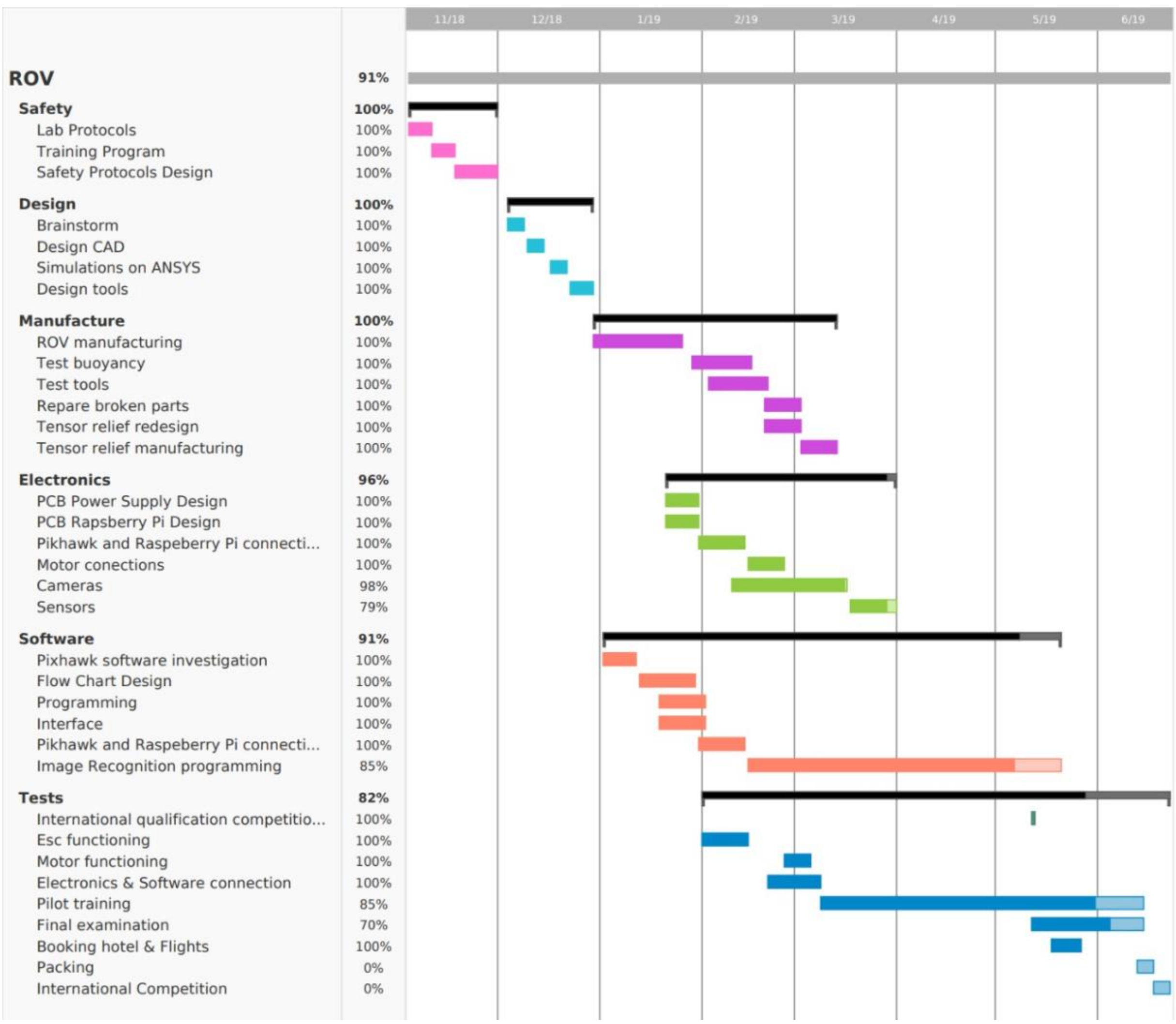
Tools	TO-002	HATCHBOX 3D PLA-1KG1.75-WHT PLA 3D P	HATCHBOX 3D PLA-1KG1.75-WHT PLA 3D Printer Filament, Dimensional Accuracy +/- 0.05 mm, 1 kg Spool, 1.75 mm, Orange	Amazon	2	Roll	$ 32.00	$ 64.00	Donated
Tools	TO-003	Advanced Sanding Sheets (6-Pack)	Pro Grade Precision 9 in. x 11 in. 80, 150, 220 Assorted Grits Advanced Sanding Sheets (6-Pack)	Home Depot	1	piece	$ 6.97	$ 6.97	Purchased
Tools	TO-004	Servomotor - TowerPro SG-5010	Servomotor - TowerPro SG-5010	Adafruit	2	piece	$ 12.15	$ 24.30	Purchased
Tools	TO-005	FUTUBA Geared DC Motor	FUTUBA Geared DC Motor	FUTUBA	2	piece	$ 27.00	$ 54.00	Purchased
Tools	TO-006	ROD-CYLINDER	SMC C95SDB32-125 TIE-ROD CYLINDER	SMC	1	piece	$ 108.00	$ 108.00	Re-Used
Tools	TO-007	Gripper	PHD 19032-5-5022 Angular - parallel gripper	PHD	1	piece	$ 120.00	$ 120.00	Re-Used
Trusters	TR-001	T100 Thruster	The T100 Thruster is a patent-pending underwater thruster designed specifically for marine robotics. It's high performing with over 5 pounds of thrust and durable enough for use in the open ocean at great depths.	Blue Robotics	4	piece	$ 119.00	$ 476.00	Re-Used
Trusters	TR-002	T200 Thruster	The T200 Thruster is a patent-pending underwater thruster designed specifically for marine robotics. Versus the T100 Thruster, the T200 is better for larger vehicles and especially for human-carrying vehicles. 3.55 Kgf	Blue Robotics	2	piece	$ 169.00	$ 338.00	Re-Used
Water Enclousure	WE-001	Acrylic Tube	Cast Acrylic Tube - 11.75", 298mm (4" Series)	Blue Robotics	1		$ 54.00	$ 54.00	Re-Used
Water Enclousure	WE-002	O-Ring Flange	This flange has a double O-ring seal that fits the tube for the 4" Series Water Tight Enclosure. Comes with O-rings.	Blue Robotics	2	piece	$ 29.00	$ 58.00	Re-Used
Water Enclousure	WE-003	Dome end CAP	Dome end cap for use on Watertight Enclosure for ROV/AUV (4" Series). Rated to 500m (1640 ft) water depth	Blue Robotics	1	piece	$ 39.00	$ 39.00	Re-Used
Water Enclousure	WE-004	Aluminum End Cap with 10 Holes (4" Series	This aluminum end cap with 10 holes is for use on the 4" Series Watertight Enclosure.	Blue Robotics	1	piece	$ 24.00	$ 24.00	Re-Used
			This vent allows trapped pressure to escape from an enclosure after it has been closed. Based on the cable penetrator design, it includes a threaded plug with						
Water Enclousure	WE-006	Cable penetrator for 6 mm	This cable penetrator makes a waterproof, high-pressure seal to pass the thruster cable into a water-tight enclosure. Each set includes a bolt, nut, and o-ring. Some assembly required.	Blue Robotics	4	piece	$ 5.00	$ 20.00	Re-Used
Water Enclousure	WE-007	Cable penetrator for 8 mm	This cable penetrator makes a waterproof, high-pressure seal to pass the thruster cable into a water-tight enclosure. Each set includes a bolt, nut, and o-ring. Some assembly required.	Blue Robotics	3	piece	$ 4.00	$ 12.00	Re-Used
Water Enclousure	WE-008	Cable Penetrator Blank (No Hole)	This blank cable penetrator is used to seal any unused holes on your watertight enclosure with a high-pressure seal. Each set includes a bolt, nut, and o-ring.	Blue Robotics	2	piece	$ 4.00	$ 8.00	Re-Used
Water Enclousure	WE-009	Loctite Marine Epoxy	Loctite Epoxy Marine is a two-part system consisting of an epoxy resin and a hardener. It can be applied and cured underwater, and it is sandable, but not paintable.	Blue Robotics	2	piece	$ 6.00	$ 12.00	Donated
Water Enclousure	WE-010	Epoxy resin & catalyzer	Epoxy resin & catalyzer can with 500 ml	Home Depot	1	Can	$ 21.60	$ 21.60	Purchased
							Total	$ 4,970.26	

Scheduled Project Management

This year, TecXotic decided to use a different project management method. Instead of starting with the Design department, a Plan, Design, Build, Test & Final Examinations (PDBTFE) system was implemented.

The following Gantt chart demonstrates the followed-up process since November form TecXotic. A difference from past years, Safety was first implemented with the sole purpose of generating a friendly work environment, starting employees' relationships.

Every week, a meeting took place with the leaders of each area, discussing the week outcomes and defining the next week operations.



Troubleshooting & Testing Techniques

TecXotic began its troubleshooting process though Root Analyze Repair (RAR) system. When a problem was presented, a series of test were made until full localization of the problem. Depending on the area and the magnitude of the situation, employees were gathered to start a brainstorm session, where returning to the basics was the key to find the root of the problem. This method prevented the company from time loss.

Once the root was located, the second part of the brainstorming session derived on analyzing the possible outcomes depending on the different solutions employees proposed. When a suitable solution was made, employees were encouraged to immediately repair the problem before it became a bigger one.

The ROV was fully tested on each and every one of the final stages of its manufacturing process. Individual tools and components were testes prior to incorporation to the final design, preventing damage onto completed pieces. Once the design and manufacturing process and testing was completed, the decides were installed onto the ROV for a dry run test before a controlled test underwater. If the ROV didn't completed the dry run test requirements, the RAR system came into place, but if the dry run test came out clean, underwater tests face began.

Conclusions

Challenges

Since it was our first year introducing new systems for project management, safety and troubleshooting and testing, employees got a hard time understanding the dynamics at the very beginning, causing tension between areas and miscommunications between head departments and employees themselves. For example, late arrival of the material caused delays on the Mechanics department, which caused Electronics department to stand by their operations due to the lack of structure needed for measuring specific pieces, or Software department having delays, causing tension between Electronics and Mechanics departments. To address these situations, a weekly meeting was scheduled in order to improve communication, leading to a friendly workspace for employees and a better staff deliverance.

Lessons Learned

This year, TecXotic learned about development of processes. At the beginning of the season, a large amount of new recruits was added, surpassing oldest members, causing troubles at task designation as a result of distress from being the new guys. It was encouraged to older members to engage in conversation and approach the new members activating a co-worker's relationship.

Future Improvements

TecXotic had its most important year when it comes to improvements. New materials were implemented, new CPU were discovered, project management decisions, among others.

For next year, TecXotic would like to expand the team, not only on the field of engineering, but also con marketing and communications. This way, the final ROV will be the result of the synergy from these areas and a more complete product.

Acknowledgements

This year, Tecxotic ROV Team, Axolotl, would like to extend our deepest gratitude to the following benefactors:

- Marine Advanced Technology Education Center
- Tecnológico de Monterrey Campus Cuernavaca and Director Mtro. Jose Antonio Moya Peredo - For being our alma mater, funding the ROV materials, components and all the support given to the team through all these rough months.
- Ing. David García Suarez - For being our mentor, for all the extra time he dedicated to the project, guiding us on decision making, always leading us with patience.
- Ph.D. Jorge Álvarez, Director of the School of Engineering and Sciences in Tecnológico de Monterrey in Cuernavaca - For authorizing this project, allocate budget for the ROV costs, and her unconditional support.
- Ph.D. Wilmer Gaona and its NOVUS project: "MakerLab: Microlaboratorio de fabricación digital para el desarrollo de prototipos y a través del prototipado rápido" for showing us the 3D printing desktop technology and its possibilities for a obtain a functional prototype from a digital design
- Ofelia Sosa, Ignacio Merlín, Juan Aguirre, Alfredo Nava, Salvador Fuentes- For their valuable time and teaching us how to use the machinery at their laboratories to manufacture the ROV.
- All the Tecnológico de Monterrey masters, teachers, engineers and community that supported our team by helping us in every possible way.

Appendices

SAFETY CHECKLIST

Pre-Power

- Clear area (no tripping hazards or items in the way)
- Verify power switches are off
- Tether flaked out on deck
- Tether connected to control station and secured to ROV
- Tether strain relief connected to ROV
- WER sealed
- Perform visual inspection of WER for damaged wires and/or loose connections
- Nuts tight on WER
- Thrusters free from obstructions
- Power source connected
- Vacuum test of WER
- Check vacuum port is securely capped

Power Up

- Power supplying 48 volts nominal
- Computers up and running
- Ensure deck crew members are attentive
- Call out "Power On"
- Wait for thrusters and esc to be armed
- Perform thruster test/verify thrusters are working properly

Launch

- Call out "Prepare to launch"
- Deck crew members handling ROV call out "hands on"
- Launch ROV maintain hand hold
- Wait for release order

In Water

- Check for bubbles
- Visually inspect for water leaks
- If there are any large bubbles, pull to surface immediately
- Check leak detector
- Arm thrusters and begin operations

ROV Retrieval

- Pilot calls "ROV surfacing"
- Deck crew calls "ROV captured", kill thrusters
- Operation Technician (OT) powers down power supply
  OT calls out "safe to remove ROV"
- After securing the ROV on deck, deck crew calls out "ROV secured on deck"

Leak Detection Protocol

- Surface immediately
- Power-down fuse box
- Inspect (may require removal of electronics)

Loss of Communication

- Cycle power on power supply to reboot ROV
- If no communication, power down ROV, retrieve via tether
- If communication restored, confirm there are no leaks, resume mission

Pit Maintenance

- Verify thrusters are free of foreign objects and spin freely
- Visual inspection for any damage
- All cables are neatly secured
- Visual inspection for leaks
- Verify camera positions
- Wash-down thrusters with deionized water